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# FIRE FINISHING OF GLASSWARE

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*In early 1952 the American Gas Association's Glass and Ceramics Committee requested the author to prepare a technical paper on this subject, which has variously also been called fire polishing and fire glazing. The paper subsequently appeared in* THE GLASS INDUSTRY,* *and because it was apparently the only published article on the subject, has been distributed rather widely in reprint form. Enough new developments have occurred during the intervening years to merit the republication of the original article, with the more recent information added.*

Fire finishing may be defined as the process in which glass is heated and molten surfaces are changed only by the surface tension of the glass. As best known by glass men, fire finishing is a variety of methods for using flame to improve strength and surface quality of glassware as formed, by reducing mold marks and grinding marks, by sealing incipient cracks and fissures, and by increasing surface smoothness and lustre. Although blast-type, natural gas-air combustion equipment is usually employed, oxygen and other gases, including hydrogen, have been occasionally used to meet special requirements.

The fire-finishing operation is best performed directly after forming, and before the temperature drops to the annealing point; that is, before the annealing operation. Some types of processing, of course, require fire finishing after operations have been performed at room temperature. In such cases it is usually necessary to reheat the ware to temperatures in the annealing range before this fire finishing can be safely performed. Regardless of where the fire finishing operation is performed, in terms of its position in the work cycle, optimum performance requires recognition of *five basic requirements*:

*1.* Burner equipment must be selected which distinguishes between heating of ware bodies and fusion of edges or surfaces. It is now well known that glasses which admit radiant energy—and this includes most commonly used formulas—are by this means heated both internally and externally at the same time. For preheating and for annealing, significant advantages of controlled radiant heating have been clearly demonstrated.

In fire-finishing operations, excessive proportions of radiant heat can, and often do, soften ware bodies and cause disastrous loss of shape before surfaces are adequately fused. Both laboratory investigation and operating experience combine to indicate burner types for fire finishing which produce surface heating primarily, with a minimum of radiant energy. Radiant heat from incandescent surfaces or luminous flames should therefore be confined either to preheating before fire finishing or to annealing afterward.

Sharp "blue" flames emit relatively little radiant

* See THE GLASS INDUSTRY, 33, 356-358, 378, (1952).

Fig. 1. Qual-O-Rimeter instrument used to detect changes of air-gas proportion in unburned mixture.

Fig. 3. Crown finishing as bottles enter annealing lehr.

energy and do a satisfactory fire-finishing job when properly handled. By way of illustration, when a New York State container plant experienced difficulty in finishing bottle mouths, analysis showed that execessive radiant heat in the transfer arm burner was softening bottle necks so that acceptable tolerances were exceeded. Replacement with a suitable multiport burner of the "blue" flame type satisfactorily corrected the condition.

*2.* Burners must permit separate and independent control over flame retention and flame quality. When used with slower burning natural gases, much of the older burner equipment designed for faster burning fuels has required a compromise gas-air ratio adjustment between that which produces the best ware and that which is necessary to keep the flame on the burner. With faster burning gases, compromise adjustment is often required to prevent flashback into the mixture line. Obviously, compromise flame settings can reduce the speed and effectiveness of any heating operation.

*3.* Control over flame geometry. Burners should be selected which maintain flames of fixed form against edges being fused. The exception to this is that operation intended to melt over-all surfaces for increasing lustre. Confinement of flame shape may be accomplished with standard burners, or burners may be specially designed for flame shaped to the ware. It will be readily understood that this third requirement implies departure from the once much-used wandering flames which played indiscriminately over the ware. Flame confinement not only provides greater control over the operation, but also improves nearby working conditions and can save much in gas consumption.

*4.* Flame chemistry must remain quite constant. This does not refer to the numerous and complex chemical reactions within the flame, but rather means that overall combustion should in most instances be held slightly

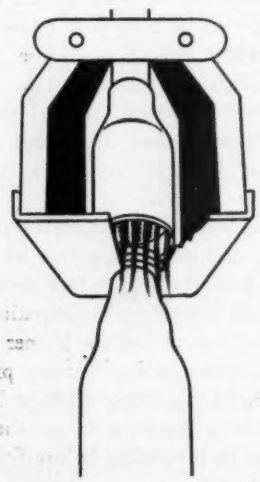

Fig. 2. Fire finishing within the arm transferring bottle from forming machine.

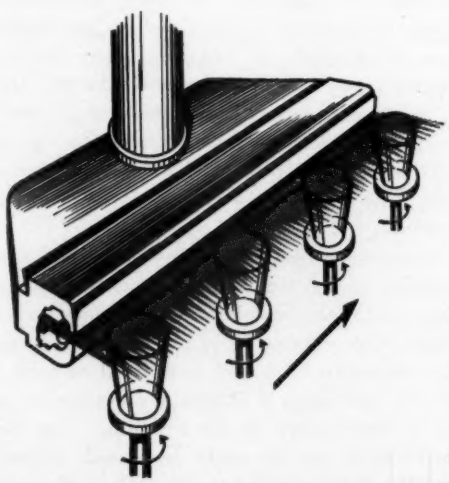

Fig. 4. Fusion of table tumbler lips during rotary-horizontal travel before straight-line flame retaining burner.

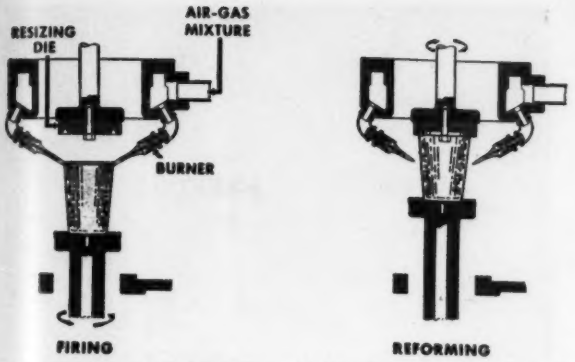


Fig. 5. Diagram showing firing of tumbler lips by ring of directed burners during spindle rotation.

oxidizing against the ware under all operating conditions on the line. As is well known, a reducing flame often discolors ware through the resulting reduction of oxides in the glass to elemental metals. This condition has been lately observed in lead glass, opal glass, and titania-bearing compositions.

Instruments are now available which will provide prompt and accurate indication of any change from optimum fuel-air ratio in lines carrying unburned mixtures to the burners. Such an instrument is shown in Fig. 1. Recent application of these instruments has revealed significant variations in mixture composition from some of the mixing devices which now supply fire-finishing burners in production plants. This means, of course, that a mixing device subject to variation should be set far enough on the oxidizing side so that during its periods of greatest deviation, flames will not become reducing to the ware. And if the device should be an air-jet or gas-jet mixer of the ordinary type, no valves or burner changes should be permitted downstream from the mixer.

*5.* A rather obvious requirement: the rate of burning must remain constant for any type of ware. If ware flows steadily past the fire-finishing station, there is certainly an optimum steady heat input rate. While greater input than this rate will overheat the ware, too much less will leave the job undone. Therefore, constant mixture pressure should be maintained ahead of the burner. Approximately two years ago we were called to a pressed ware plant with fire-finishing difficulties, and when the plant manager asked whether it was necessary to purchase gas pressure regulators for his fire-finishing equipment, one reason for his troubles became quite apparent.

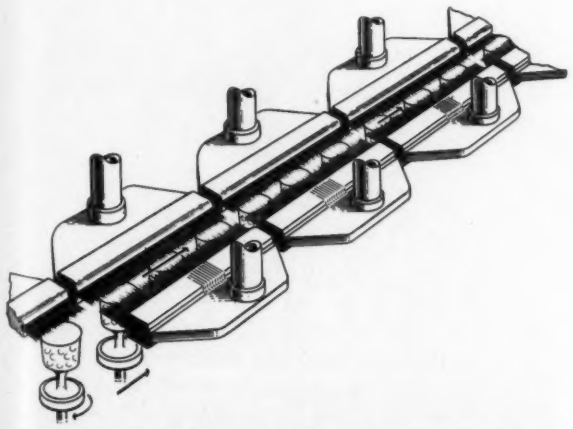

Fig. 6. Fire finishing of pressed tableware was substantially improved by acceptance of FIVE REQUIREMENTS here.

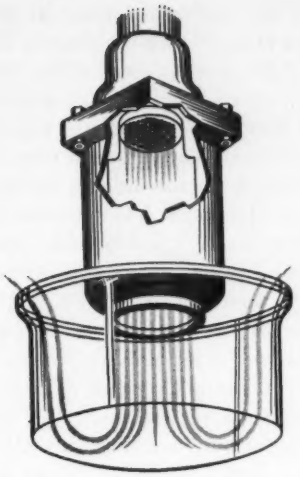

Fig. 7. Glazing of meter case interior surface beneath vertical burner.

In the foregoing paragraphs the *five requirements* for good fire finishing have been outlined briefly. The remainder of this article will be devoted to the more frequently encountered types of fire-finishing operations, with illustrations and descriptions of how they are being satisfactorily performed.

### *Beverage Bottles*

The most frequently employed fire-finishing operation

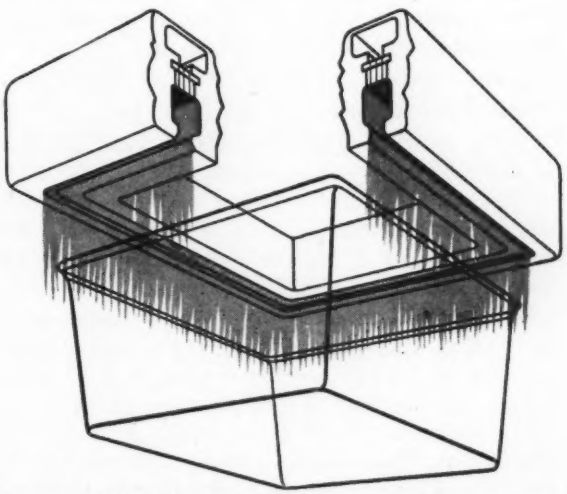

Fig. 8. Finishing borosilicate baking dish with burner shaped to the ware.

is that used for crowns and necks of beverage bottles because these must be very smooth and free from sharp edges. On older installations this has been handled by installing a burner in each takeout arm of the forming machine, as shown schematically in Fig. 2.

As bottle-forming machine speeds have increased, time for fire-finishing in the takeout arm has been proportionately reduced. Extensive investigations with most advanced air-gas burner types for this service indicate a minimum time requirement for satisfactory finish of between 3 and 4 seconds under the flame. While crown-finishing time has been reduced to 2 seconds or less by employing oxygen or air preheat, very few bottle manufacturers are willing to add either of these complications to their manufacturing methods. Therefore, because today's faster forming machines provide too short an interval (less than 3 seconds), the crown-finishing operation has been largely removed to the transfer conveyor or to the lehr entrance.

Cover shows a double-line application of a successful transfer conveyor crown finisher, while Fig. 3 pictures bottles being finished at the lehr entrance. In both of these locations, flame finishing is not only employed on the rims, but also down the necks for some distance.

### *Water Tumblers and "Jellies"*

Whether its first purpose is as a drinking glass or as a container for preserves or other spreads, the rim of such wide-mouthed ware is usually fire finished to protect the user. This operation is normally performed while ware rotates on a fire-glazing machine, in either straight-line or circular travel. Especially designed burners may fire against either one or two sides of the passing ware (Fig. 4), or a specially assembled burner ring may fire from above as the ware is followed along the conveyor (Fig. 5). In either method, a small portion of the travel time is usually employed to flame wash the sidewalls for improving surface clarity. This may be accomplished either by directing one or more of the burners below the rim, or by lifting the rotating ware through the burner ring.

### *Pressed Table Ware*

Plates, saucers, goblets, and similar ware are often pressed with "cut glass" patterns and are made from opal as well as colored and clear compositions. These are regularly fire finished, both to remove undesirable mold marks and to improve surface lustre. Although many types of equipment have been used for the purpose, it has definitely been established that better equipment which adequately fulfills all of the foregoing *five requirements* both increases production and minimizes rejects. This has been particularly true with opal ware, where careless fire finishing can quickly result in ware discoloration. Fig. 6 diagrammatically pictures a recently installed and highly successful fire-finishing line for these types of ware.

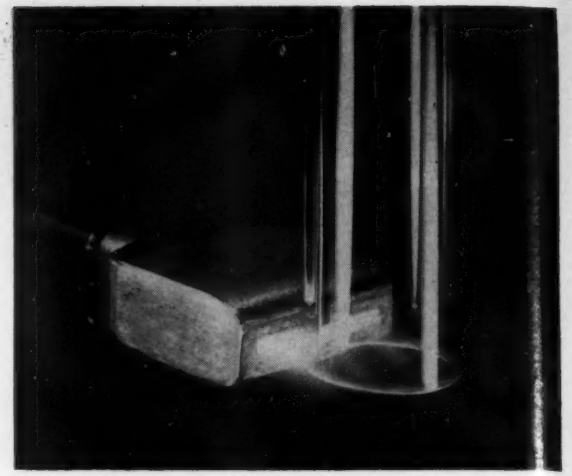

Fig. 9. Fusing end of large borosilicate glass tube.

### *Other Pressed Ware*

In addition to tableware, many other pressed ware items require fire finishing. Among these are "solid" objects such as door knobs and ash trays, and hollow ware such as electric meter cases shown in Fig. 7. The former are thus finished to remove cutting edges, and the latter, to increase clarity. While exterior surfaces can be treated much as are exterior surfaces of water tumblers and other pressed tableware, interior surfaces are most satisfactorily finished by employing burners which direct flames in such a manner that they wash the entire surface. The burner shown in Fig. 7 is actually a miniature furnace whose hot flue gases are largely preburned and discharged at relatively low velocities through a nozzle shaped to the ware.

### *Baking Dishes*

Baking dishes are a special type of pressed ware long made from borosilicates, and now more recently from

(*Continued on page* 223)

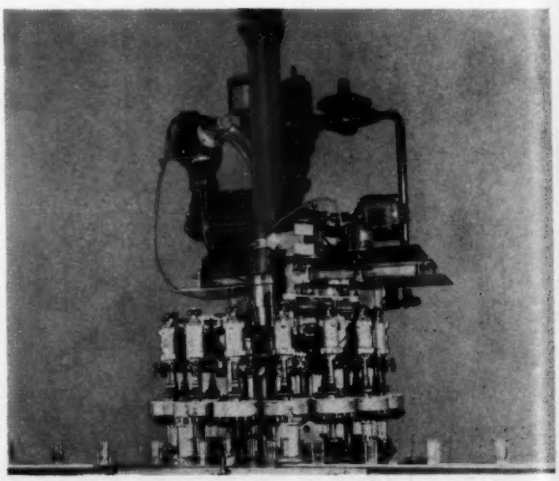

Fig. 10. Fire-finishing machine for table tumblers and similar ware.

# RUBIDIUM in Lime and Borate Glasses

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VARIOUS properties of lead and barium glasses, which use rubidium carbonate as the sole source of alkali, have recently been reported by the author.*

In the light of this earlier work, the chief advantage of using rubidium as an alkali in these glasses appeared to be the development of stable and reasonably durable glasses of higher-than-usual alkali content. Rubidium also seemed to raise the coefficient of expansion, and, therefore, small amounts of this material may be effective in controlling this physical property in glass. This type of alkali, on the other hand, appeared to provide a more refractory glass with higher viscosity that may demand a higher melting temperature. The Littleton softening point was also higher than for corresponding soda or potash glasses with the result that possible higher working temperatures may be needed. No actual durability tests were determined, but there was every indication that these glasses possessed good durability, especially in their resistance to atmospheric moisture. There was no evidence of dimming of the surface of the better glasses when exposed to normal atmospheric moisture for prolonged times. Glasses made with a 35 to 40 per cent (weight per cent) rubidium content apparently possessed very good resistance.

Considering the fact that work had already been done utilizing lead oxide (PbO), as well as barium oxide (BaO), it was deemed logical to study the effects of rubidium oxide in $Rb_2O$–$CaO$–$SiO_2$ systems and $Rb_2O$–$B_2O_3$–$SiO_2$ systems which correspond to present-day soda-lime-silica glasses and alkali-boron-silica glass systems. These glasses are recognized as being most practical and correspond to the commercial lime and borosilicate glasses.

## *Experimental Work*

### *Raw Materials*

All the raw materials used were c.p. glass grade materials of high purity corresponding to those normally used in the glass industry.

The rubidium carbonate was analyzed as follows.

| | |
|---|---|
| $Rb_2CO_3$ | 96.70 per cent |
| $CsHCO_3$ | 0.14 per cent |
| $KHCO_3$ | 2.53 per cent |
| $Na_2CO_3$ | 0.32 per cent |
| ZnO | 0.02 per cent |
| $SiO_2$ | 0.27 per cent |
| $NO_3$ | 0.02 per cent |

The boric oxide or boric anhydride ($B_2O_3$) had the following analysis.

| | | |
|---|---|---|
| $B_2O_3$ | | 99.00 per cent (Minimum) |
| $Na_2SO_4$ | * | 0.02 per cent |
| $H_2O$ | | 0.88 per cent (Diff.) |

The $B_2O_3$ was a colorless, hard, brittle, glass-like solid, apparently ideal for use as a glass raw material in that it gave no evidence of any appreciable absorption of moisture.

The CaO was supplied by a raw limestone of glass grade purity of 99.0 per cent plus $CaCO_3$.

The glass sand was approximately 99.9 per cent $SiO_2$.

### *Melting*

All glasses were fused in high quality porcelain crucibles. They were fused to quiet fusion, and because the borosilicate glasses varied considerably in their refractoriness, we are listing their firing temperature in Table VI.

When the melting was completed, the glasses were poured onto a previously heated iron plate and cast into buttons 1 to 2 in. in diameter and about ¼ in. thick.

After casting, each sample was immediately put into an annealing oven and slowly cooled from 1000°F in order to relieve the strains. The melting characteristics, ease of pouring, viscosity, color, and general working characteristics of the glass were observed. Any corrosion of the refractory was also noted.

### *Lime Glasses Studied*

The triaxial diagram (Fig. 1) indicates the various members possible when plotted at 10 per cent (weight per cent) intervals. The better glasses are indicated by the shaded area.

### *Borate Glasses Studied*

The triaxial diagram (Fig. 2) indicates the various

*Rubidium in Lead and Barium Glasses, THE GLASS INDUSTRY, *40*, 411-17, 454-57, (1959).

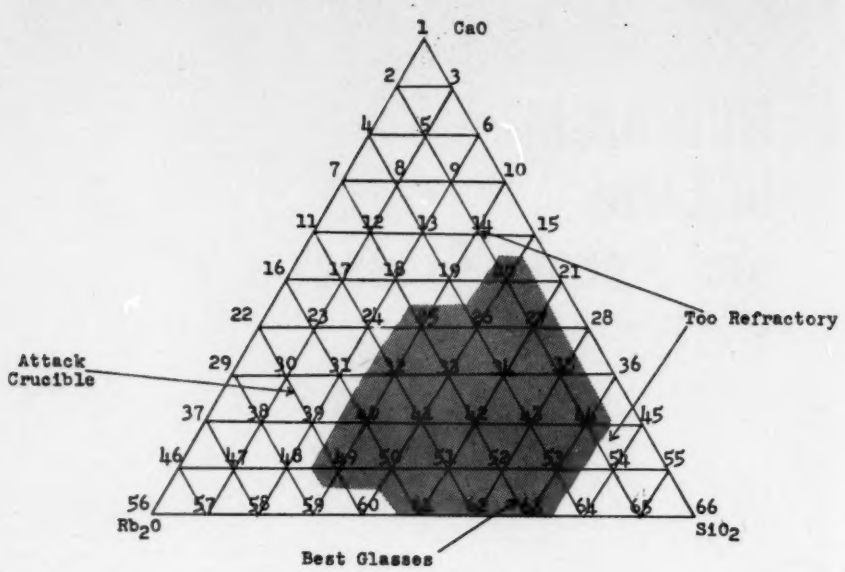


Fig. 1. Lime glasses studied.

members possible when plotted at 10 per cent (weight per cent) intervals. The better glasses are indicated by the shaded area.

### *Physical Properties*

In order to evaluate these glasses more throughly, the physical properties of density, refractive index, Littleton's softening point, and coefficient of expansion were determined for the more promising glasses. So that samples may be properly identified, reference should be made to the triaxials (Fig. 1 and Fig. 2), as well as to Table I and Table II, describing the raw batch and composition of the various members.

Density[1], index of refraction[2], and Littleton's softening point[3] were determined by well-known and common procedures given in the respective references.

### *Coefficient of Expansion by Dial Gage*

In common with most other substances, glasses expand when heated and contract when cooled. The magnitude of this change, which varies according to the composition of the glass, is expressed numerically as the coefficient of expansion. The linear coefficient, $\alpha$, refers to the fraction of its length by which a piece of glass expands for a rise in temperature of 1°C. Because the expansion

1. G. W. Morey, *The Properties of Glass*, Reinhold Publishing Corporation, New York (1938), 379-381.
2. H. Insley and V. D. Frechette, *Microscopy of Ceramics and Cements*, Academic Press, Inc., New York (1955).
3. J. T. Littleton, J. Am. Cer. Soc. *10*, 259-263 (1927)

TABLE I

RAW BATCH AND PER CENT COMPOSITION OF LIME GLASSES STUDIED

| Glass | Raw Batch By Wt. (Grams) | | | Per cent Composition of Oxide | | | Mole Per Cent | | |
|---|---|---|---|---|---|---|---|---|---|
| Number | $Rb_2CO_3$ | $CaCO_3$ | $SiO_2$ | $Rb_2O$ | CaO | $SiO_2$ | $Rb_2O$ | CaO | $SiO_2$ |
| 20 | 12.4 | 89.3 | 40.0 | 10.0 | 50.0 | 40.0 | 3.3 | 55.3 | 41.4 |
| 25 | 37.1 | 71.5 | 30.0 | 30.0 | 40.0 | 30.0 | 11.6 | 52.0 | 36.4 |
| 26 | 24.7 | 71.5 | 40.0 | 20.0 | 40.0 | 40.0 | 7.3 | 48.0 | 44.7 |
| 27 | 12.4 | 71.5 | 50.0 | 10.0 | 40.0 | 50.0 | 3.3 | 44.6 | 52.1 |
| 32 | 49.5 | 53.5 | 30.0 | 40.0 | 30.0 | 30.0 | 17.2 | 42.8 | 40.0 |
| 33 | 37.1 | 53.5 | 40.0 | 30.0 | 30.0 | 40.0 | 11.7 | 39.3 | 49.0 |
| 34 | 24.7 | 53.5 | 50.0 | 20.0 | 30.0 | 50.0 | 7.3 | 36.2 | 56.5 |
| 35 | 12.4 | 53.5 | 60.0 | 10.0 | 30.0 | 60.0 | 3.4 | 33.6 | 63.0 |
| 40 | 61.8 | 35.7 | 30.0 | 50.0 | 20.0 | 30.0 | 23.8 | 31.8 | 44.4 |
| 41 | 49.5 | 35.7 | 40.0 | 40.0 | 20.0 | 40.0 | 17.3 | 28.8 | 53.9 |
| 42 | 37.1 | 35.7 | 50.0 | 30.0 | 20.0 | 50.0 | 11.8 | 26.4 | 61.8 |
| 43 | 24.7 | 35.7 | 60.0 | 20.0 | 20.0 | 60.0 | 7.3 | 24.4 | 68.3 |
| 44 | 12.4 | 35.7 | 70.0 | 10.0 | 20.0 | 70.0 | 3.4 | 22.6 | 74.0 |
| 49 | 74.0 | 17.9 | 30.0 | 60.0 | 10.0 | 30.0 | 32.1 | 17.9 | 50.0 |
| 50 | 61.8 | 17.9 | 40.0 | 50.0 | 10.0 | 40.0 | 24.0 | 16.0 | 60.0 |
| 51 | 49.5 | 17.9 | 50.0 | 40.0 | 10.0 | 50.0 | 17.4 | 14.6 | 68.0 |
| 52 | 37.1 | 17.9 | 60.0 | 30.0 | 10.0 | 60.0 | 12.0 | 13.4 | 74.6 |
| 53 | 24.7 | 17.9 | 70.0 | 20.0 | 10.0 | 70.0 | 7.4 | 12.3 | 80.3 |
| 61 | 61.8 | — | 50.0 | 50.0 | — | 50.0 | 24.3 | — | 75.7 |
| 62 | 49.5 | — | 60.0 | 40.0 | — | 60.0 | 17.6 | — | 82.4 |
| 63 | 37.1 | — | 70.0 | 30.0 | — | 70.0 | 12.1 | — | 87.9 |

TABLE II

RAW BATCH AND PER CENT COMPOSITION OF BORATE GLASSES STUDIED

| Glass Number | Raw Batch By Wt. (Grams) | | | Per cent Composition of Oxide | | | Mole Per Cent | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Rb_2CO_3$ | $BaCO_3$ | $SiO_2$ | $Rb_2O$ | $B_2O_3$ | $SiO_2$ | $Rb_2O$ | $B_2O_3$ | $SiO_2$ |
| 12 | 36.9 | 10.0 | 60.0 | 30.0 | 10.0 | 60.0 | 12.4 | 10.8 | 76.8 |
| 13 | 24.6 | 20.0 | 60.0 | 20.0 | 20.0 | 60.0 | 7.9 | 20.7 | 71.4 |
| 17 | 49.2 | 10.0 | 50.0 | 40.0 | 10.0 | 50.0 | 17.8 | 11.9 | 70.3 |
| 18 | 36.9 | 20.0 | 50.0 | 30.0 | 20.0 | 50.0 | 12.5 | 22.7 | 64.8 |
| 19 | 24.6 | 30.0 | 50.0 | 20.0 | 30.0 | 50.0 | 8.0 | 31.4 | 60.6 |
| 23 | 61.5 | 10.0 | 40.0 | 50.0 | 10.0 | 40.0 | 25.0 | 13.0 | 62.0 |
| 24 | 49.2 | 20.0 | 40.0 | 40.0 | 20.0 | 40.0 | 17.9 | 24.8 | 57.3 |
| 25 | 36.9 | 30.0 | 40.0 | 30.0 | 30.0 | 40.0 | 12.7 | 34.1 | 53.2 |
| 26 | 24.6 | 40.0 | 40.0 | 20.0 | 40.0 | 40.0 | 8.1 | 42.2 | 49.7 |
| 31 | 61.5 | 20.0 | 30.0 | 50.0 | 20.0 | 30.0 | 25.5 | 27.4 | 47.1 |
| 32 | 49.2 | 30.0 | 30.0 | 40.0 | 30.0 | 30.0 | 18.4 | 37.7 | 43.9 |
| 33 | 36.9 | 40.0 | 30.0 | 30.0 | 40.0 | 30.0 | 13.0 | 46.3 | 40.7 |
| 34 | 24.6 | 50.0 | 30.0 | 20.0 | 50.0 | 30.0 | 8.3 | 53.8 | 37.9 |
| 35 | 12.3 | 60.0 | 30.0 | 10.0 | 60.0 | 30.0 | 3.5 | 61.0 | 35.5 |
| 0 | 61.5 | 30.0 | 20.0 | 50.0 | 30.0 | 20.0 | 26.2 | 41.8 | 32.0 |
| 1 | 49.5 | 40.0 | 20.0 | 40.0 | 40.0 | 20.0 | 18.9 | 51.4 | 29.7 |
| 2 | 36.9 | 50.0 | 20.0 | 30.0 | 50.0 | 20.0 | 13.3 | 59.2 | 27.5 |
| 3 | 24.6 | 60.0 | 20.0 | 20.0 | 60.0 | 20.0 | 8.5 | 66.1 | 25.4 |
| 4 | 12.3 | 70.0 | 20.0 | 10.0 | 70.0 | 20.0 | 3.6 | 72.5 | 23.9 |
| 0 | 61.5 | 40.0 | 10.0 | 50.0 | 40.0 | 10.0 | 26.7 | 56.5 | 16.8 |
| 1 | 49.2 | 50.0 | 10.0 | 40.0 | 50.0 | 10.0 | 19.3 | 65.1 | 15.6 |
| 2 | 36.9 | 60.0 | 10.0 | 30.0 | 60.0 | 10.0 | 13.4 | 72.3 | 14.3 |
| 3 | 24.6 | 70.0 | 10.0 | 20.0 | 70.0 | 10.0 | 8.6 | 78.1 | 13.3 |
| 4 | 12.3 | 80.0 | 10.0 | 10.0 | 80.0 | 10.0 | 15.2 | 33.3 | 51.5 |

is not uniform over all temperature ranges, it is desirable when calculating the coefficient to specify the interval (a common temperature range is from O°C to 300°C) over which the expansion is measured. The change in dimensions of a sample rod of glass 4 to 5 in. long was measured by means of a dial gage, and the linear coefficient of thermal expansion was then calculated.

*Durability Tests*

No durability tests as such were carried out with these glasses; that is, no powder tests, autoclave, or so-called "solubility" tests were made. The appearance of "bloom" or surface chalking was carefully observed, and when such conditions were found, the facts were recorded in the results. The resistance to atmospheric corrosions

TABLE III

PHYSICAL PROPERTIES OF $Rb_2O$—CaO—$SiO_2$ GLASSES

| Glass Number | Per Cent Composition of Oxide | | | Density | Index of Refraction ($N_d$) | Littleton's Softening Point (°C.) $\log \eta = 7.65$ | Coefficient of Expansion ($\alpha$) 0-300°C. ($\times 10^{-7}$) | Calculated $K_2O$—CaO—$SiO_2$ Coefficient of Expansion ($\alpha$) 0-300°C. ($\times 10^{-7}$) |
|---|---|---|---|---|---|---|---|---|
| | $Rb_2O$ | CaO | $SiO_2$ | | | | | |
| 20 | 10.0 | 50.0 | 40.0 | 2.86 | 1.610 | 962 | 163 | 111.8 |
| 25 | 30.0 | 40.0 | 30.0 | 2.88 | 1.615 | 854 | 206 | 151.6 |
| 26 | 20.0 | 40.0 | 40.0 | 2.97 | 1.615 | 912 | 170 | 124.8 |
| 27 | 10.0 | 40.0 | 50.0 | 3.02 | 1.610 | 945 | 130 | 96.0 |
| 32 | 40.0 | 30.0 | 30.0 | 2.97 | 1.600 | 805 | 222 | 163.6 |
| 33 | 30.0 | 30.0 | 40.0 | 2.91 | 1.595 | 838 | 185 | 135.8 |
| 34 | 20.0 | 30.0 | 50.0 | 2.84 | 1.595 | 878 | 145 | 108.0 |
| 35 | 10.0 | 30.0 | 60.0 | 2.73 | 1.585 | 903 | 109 | 80.2 |
| 40 | 50.0 | 20.0 | 30.0 | 2.94 | 1.580 | 772 | 224 | 165.6 |
| 41 | 40.0 | 20.0 | 40.0 | 2.95 | 1.575 | 803 | 214 | 157.8 |
| 42 | 30.0 | 20.0 | 50.0 | 2.90 | 1.560 | 827 | 163 | 120.0 |
| 43 | 20.0 | 20.0 | 60.0 | 2.72 | 1.560 | 863 | 125 | 92.2 |
| 44 | 10.0 | 20.0 | 70.0 | 2.60 | 1.555 | 889 | 87.5 | 64.4 |
| 49 | 60.0 | 10.0 | 30.0 | 2.86 | 1.570 | 723 | 242 | 177.6 |
| 50 | 50.0 | 10.0 | 40.0 | 2.92 | 1.550 | 778 | 204 | 149.8 |
| 51 | 40.0 | 10.0 | 50.0 | 2.92 | 1.545 | 808 | 180 | 132.0 |
| 52 | 30.0 | 10.0 | 60.0 | 2.72 | 1.535 | 837 | 141 | 104.2 |
| 53 | 20.0 | 10.0 | 70.0 | 2.58 | 1.520 | 874 | 104 | 76.4 |
| 61 | 50.0 | — | 50.0 | 2.90 | 1.515 | 828 | 182 | 134.0 |
| 62 | 40.0 | — | 60.0 | 2.74 | 1.510 | 874 | 157 | 116.2 |
| 63 | 30.0 | — | 70.0 | 2.56 | 1.500 | 908 | 120 | 88.4 |

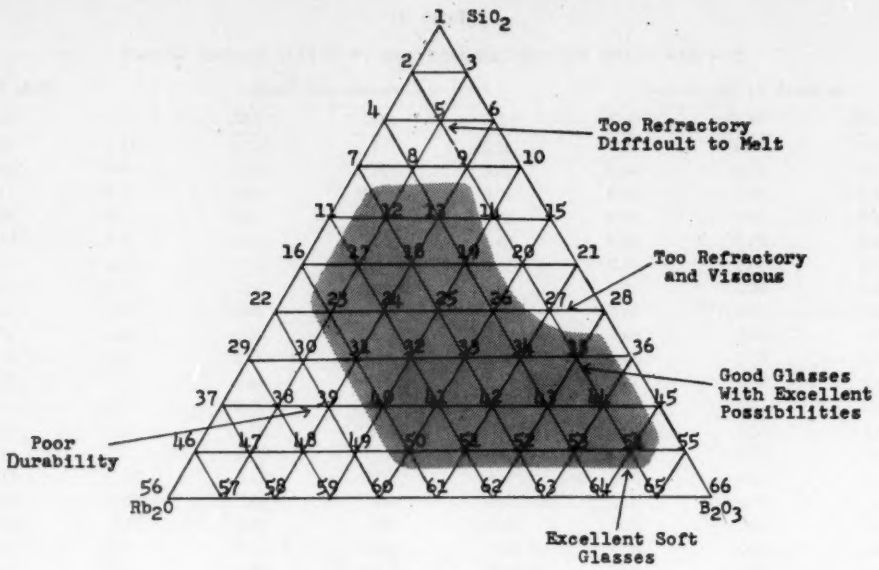


Fig. 2. Borate glasses studied.

was very good for these glasses, even at a quite high rubidium content.

### *Discussion of Results*

#### *Lime Glasses*

It was found that good glasses can be made over an extremely broad composition range.

| | |
|---|---|
| $Rb_2O$ | 10 to 60 per cent |
| CaO | 0 to 50 per cent |
| $SiO_2$ | 30 to 70 per cent |

This range of good glass compositions is exceptionally broad, and the fact that the rubidium ion ($Rb^+$) is a large one, apparently closely bonded and not mobile, appears to aid greatly in the glass formation. The range of good glasses has been considerably extended over other alkaline glasses, such as soda ($Na_2O$) and potash ($K_2O$). Because rubidium possesses sufficient viscosity at the liquidus to retard devitrification, no evidence of crystallization was observed in these glasses.

Still another advantage lies in the fact that the co-

TABLE IV

PHYSICAL PROPERTIES OF $Rb_2O$—$B_2O_3$—$SiO_2$ GLASSES

| Glass Number | Per cent Composition of Oxide | | | Density | Index of Refraction ($N_d$) | Littleton's Softening Point (°C) log $\eta = 7.65$ | Coefficient of Expansion ($\alpha$) 0-300°C (x $10^{-7}$) |
|---|---|---|---|---|---|---|---|
| | $Rb_2O$ | $B_2O_3$ | $SiO_2$ | | | | |
| 12 | 30.0 | 10.0 | 60.0 | 3.16 | 1.505 | 858 | 70 |
| 13 | 20.0 | 20.0 | 60.0 | 2.47 | 1.495 | — | 66.8 |
| 17 | 40.0 | 10.0 | 50.0 | 3.00 | 1.515 | 776 | 71 |
| 18 | 30.0 | 20.0 | 50.0 | 2.71 | 1.515 | 797 | 71 |
| 19 | 20.0 | 30.0 | 50.0 | 2.33 | 1.480 | — | — |
| 23 | 50.0 | 10.0 | 40.0 | 2.88 | 1.515 | — | — |
| 24 | 40.0 | 20.0 | 40.0 | 3.02 | 1.520 | 664 | 75.7 |
| 25 | 30.0 | 30.0 | 40.0 | 2.41 | 1.495 | 729 | 74.7 |
| 26 | 20.0 | 40.0 | 40.0 | 2.22 | 1.470 | 659 | 74.5 |
| 31 | 50.0 | 20.0 | 30.0 | 2.89 | 1.515 | — | — |
| 32 | 40.0 | 30.0 | 30.0 | 2.47 | 1.490 | 688 | 82.2 |
| 33 | 30.0 | 40.0 | 30.0 | 2.57 | 1.500 | 637 | 75.8 |
| 34 | 20.0 | 50.0 | 30.0 | 2.12 | 1.480 | — | 76.6 |
| 35 | 10.0 | 60.0 | 30.0 | 2.04 | 1.470 | — | — |
| 40 | 50.0 | 30.0 | 20.0 | 2.46 | 1.490 | 610 | 84.2 |
| 41 | 40.0 | 40.0 | 20.0 | 2.50 | 1.485 | — | — |
| 42 | 30.0 | 50.0 | 20.0 | 2.59 | 1.495 | — | — |
| 43 | 20.0 | 60.0 | 20.0 | 2.24 | 1.485 | — | — |
| 44 | 10.0 | 70.0 | 20.0 | 2.09 | 1.470 | — | — |
| 50 | 50.0 | 40.0 | 10.0 | 2.33 | 1.480 | — | — |
| 51 | 40.0 | 50.0 | 10.0 | 2.42 | 1.480 | — | — |
| 52 | 30.0 | 60.0 | 10.0 | 2.42 | — | — | — |
| 53 | 20.0 | 70.0 | 10.0 | 2.25 | — | — | — |
| 54 | 10.0 | 80.0 | 10.0 | 2.08 | — | — | — |

TABLE V

RESULTS — LIME GLASSES

| Glass Number | Glass Rating | Description of glass |
|---|---|---|
| 20 | Good | Clear, poured easily, attack crucible. |
| 25 | Fair | White inclusions, poured hard. |
| 26 | Fair | White inclusions, poured easily. |
| 27 | Good | Clear, poured easily. |
| 32 | Good | Clear, poured easily. |
| 33 | Good | Clear, poured easily. |
| 34 | Good | Clear, poured easily. |
| 35 | Good | Clear, poured easily. |
| 40 | Good | Clear, poured easily. |
| 41 | Good | Clear, poured easily. |
| 42 | Good | Clear, poured easily. |
| 43 | Good | Clear, poured easily. |
| 44 | Good | Clear, poured easily. |
| 49 | Good | Clear, poured easily, attack crucible. |
| 50 | Good | Clear, poured easily. |
| 51 | Good | Clear, poured easily. |
| 52 | Good | Clear, poured easily. |
| 53 | Good | Clear, poured hard. |
| 61 | Good | Clear, poured easily. |
| 62 | Good | Clear, poured easily. |
| 63 | Good | Clear, poured hard. |

efficient of expansion was uniformly high with all the rubidium glasses, indicating that rubidium may be used in an effective manner to control the coefficient of expansion. This control would be especially important where proper bonding and matching of glasses are desired in casing, glass sealing, glass-to-metal seals, optical lens systems, and laminations.

The durability of these glasses also appeared to be excellent, even in relatively high alkali contents. No evidence of fogging or surface scuming was noted after prolonged exposure to the atmosphere, either indoors or out.

Furthermore, the results indicated the following.

1. The density and index of refraction are generally higher than those obtained with soda-lime-silica glasses.
2. The Littleton softening point varies inversely with the addition of $Rb_2O$. Because $Rb_2O$ is a flux, this is to be expected.
3. The coefficient of expansion varied directly with the addition of $Rb_2O$. The measured values of the $Rb_2O$–$CaO$–$SiO_2$ glasses were higher than the calculated values of the $K_2O$–$CaO$–$SiO_2$ glasses.

*Borosilicate Glasses*

The field of good glasses was extremely large for this system, and it appears that the character of the $Rb^+$ ion exerts a profound influence on this type of glass. The compositions showing the best glass possibilities are listed in Table VII.

These glasses showed varying characteristics of meltability, but it was apparent from the fusion study (see Table VI) that commercial glasses are possible with these compositions.

The general results indicated that compositions greater than 60 per cent $SiO_2$ were quite refractory and would need temperatures in excess of 1538°C (2800°F) to melt. Compositions greater than 50 per cent $Rb_2O$ were of questionable durability; that is, they took up water quite readily and were quite hydroscopic. Compositions greater than 40 per cent $B_2O_3$ were amazingly soft and could be melted at about 1300°C (2300°F or less). These borate glasses showed great promise.

TABLE VI

RESULTS — BORATE GLASSES

| Glass Number | Firing Temperature | Glass Rating | Description of Glass |
|---|---|---|---|
| 12 | 2840°F | Good | Clear, brilliant gloss, quite viscous and stiff. |
| 13 | 2775°F | Good | Clear, some bubbles, fair viscous. |
| 14 | 2840°F | Good | Opaque white glass, difficult to melt and very viscous, 2840°F not high enough temperature to melt. |
| 17 | 2560°F | Excellent | Clear, fairly viscous, but poured well. |
| 18 | 2560°F | Good | Some seeds, but not melted sufficiently; fairly viscous, but poured well. |
| 19 | 2775°F | Good | Fairly viscous, but poured well. |
| 20 | 2840°F | Fair | Quite refractory and viscous, would be difficult to handle. |
| 23 | 2525°F | Good | Slight greenish-yellow color, poured easily, not very viscous. |
| 24 | 2525°F | Good | Clear, fairly viscous. |
| 25 | 2624°F | Good | Clear, poured well, not too viscous. |
| 26 | 2732°F | Good | Some bubbles, poured well. |
| 27 | 2840°F | Fair | Some bubbles, quite viscous. |
| 30 | 2435°F | Good | Slight yellow-green color, poor durability. |
| 31 | 2435°F | Good | Poured well, low viscosity. |
| 32 | 2372°F | Good | Greenish-yellow color, poured easily. |
| 33 | 2552°F | Fair | Poured easily, some bubbles. |
| 34 | 2786°F | Good | Some bubbles, quite refractory and viscous. |
| 35 | 2840°F | Good | Quite refractory and viscous. |
| 38 | 2372°F | Good | Initially good, but poor durability. |
| 39 | 2372°F | Good | Similar to 38. |
| 40 | 2372°F | Good | Clear, fairly viscous, but not refractory. |
| 41 | 2372°F | Good | Similar to 40. |
| 42 | 2372°F | Excellent | Trouble with annealing, should be annealed between 700°F and 800°F. |
| 43 | 2372°F | Excellent | Poured easily, difficulty in annealing. |
| 44 | 2372°F | Excellent | Poured well, difficulty in annealing. |
| 50 | 2462°F | Excellent | Poured well, not refractory, could be melted in electric furnace, was easy to work and seemed quite durable. |
| 51 | 2462°F | Excellent | Became easier to pour as $B_2O_3$ increased. |
| 52 | 2462°F | Excellent | Became easier to pour as $B_2O_3$ increased. |
| 53 | 2462°F | Excellent | Became easier to pour as $B_2O_3$ increased. |
| 54 | 2462°F | Excellent | Became easier to pour as $B_2O_3$ increased. |

The outstanding characteristics which $Rb_2O$ imparts to this type of glass are its high melting range, high viscosity, a lessening of the tendency to devitrify, and an improvement in durability. Glasses up to as high at 50 per cent $Rb_2O$ seemed to be practical and possible. An additional feature is that by a combination of rubidium and $B_2O_3$, apparently durable glasses are possible with as high as 80 per cent $B_2O_3$.

From the results shown in the triaxial (Fig 2), and

(*Continued on page* 222)

# Conditions of Glass Formation Among Simple Compounds* IN FOUR PARTS Part IV Concluded

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### 3. On the Relations Between Expansivities and Viscosities of Glasses

From a technological point of view it is important to find ways of changing a glass composition which will enable us to vary different properties more or less independantly from one another. The classical example is the development of new optical glass, a struggle of combating the parallelism which existed between refraction index and dispersion. In addition to the traditional crown and flint glasses new glasses were needed which had a high dispersion but a low index of refraction and others which had a low dispersion and a high index of refraction.

Similar parallelisms exist between other properties, e.g., the viscosity and the chemical resistivity of a glass and its thermal expansivity. From a practical viewpoint one of the major targets in research on the constitution of glass is to find ways of overcoming some of these interdependences of its properties.

What are the reasons for the empirical observation that most attempts to lower the melting characteristics of a glass lead to glasses which have higher thermal expansivities? What are the possibilities of lowering the thermal expansion of a glass without increasing its melting temperature or of lowering the melting temperature without raising its expansivity?

We attributed the low expansivity of silica glass to the combination of strong binding forces and high symmetry of forces within the individual $SiO_4$ tetrahedra. This combination also accounts for the high viscosity because symmetry of forces means that in order to flow the thermal energy has to overcome the average binding forces. The viscosity of silica glass cannot be lowered without increasing its expansivity because the only way of lowering the viscosity of this "flawless" liquid would be to introduce flaws or centers of asymmetry. These will disproportionate all binding forces into stronger and weaker ones and the weaker forces facilitate flow of the glass. They also decrease the harmonicity of the termal vibrations, thus raising the expansivity.

Retaining the flawless structure of the glass and weakening all binding forces equally by going from $SiO_2$ to $GeO_2$ or $BeF_2$ also leads to glasses which have higher expansivities because the weaker Ge-O and Be-F bonds permit larger amplitudes of vibrations which in turn lead to greater anharmonicity.

Replacing $SiO_2$ by an oxide which has approximately the same average bond strength, e.g., $B_2O_3$, but which forms a glass which does not have the structure of a "flawless" liquid but one of the "orientable" type lowers the viscosity but also raises the expansivity.

The interdependence of viscosity and expansivity would seem to make it impossible to vary both properties in different directions. However, it can be done. In order to do so one would have to change the composition in a way which does not lower the symmetry of forces in the rigid glass but which causes a higher concentration of defects to form in the softening region. Such a change would not affect the coefficient of expansion of the rigid glass but it would cause a stronger disproportionation of the binding forces at high temperature which in turn would lower the viscosity.

This can be achieved in two ways. The replacement of a noble gas-type ion by one of greater polarizability, e.g., of a $Sr^{2+}$ by a $Pb^{2+}$ or a $Mg^{2+}$ by a $Cu^{2+}$ ion, does not change the coefficient of expansion[17] but it permits defects to form at a lower temperature and thus lowers the viscosity[22] of the glass.

A second approach to this problem can be based on the formation of a superlattice on cooling. The replacement of some $Si^{4+}$ ions in vitreous silica by a combination of $Na^{+} + B^{3+}$ ions introduces a strong asymmetry only at high temperature. On cooling, the formation of a superlattice restores some of the symmetry.

## IV. ATOMIC STRUCTURES OF SOME GLASSES

### 1. The Structures of $SiO_2$, $GeO_2$, and $BeF_2$ Glasses

The atomic structure of vitreous silica as suggested by Zachariasen and confirmed by Warren and his school can be looked upon as a useful first approximation. The establishment of the atomic structure of vitreous silica on the basis of X-ray diffraction was possible because this glass is characterized by only one coordination number for silicon (4), one for oxygen (2), and one constant silicon-oxygen distance (1.60 A.U.). This unique simplicity of an amorphous structure is limited to vitreous $SiO_2$, $GeO_2$, and $BeF_2$.

The X-ray diffraction patterns of a glass establishes its

* Mineral Industries Contribution No. 59-95.

geometry on the basis of average distances. Scientists are now applying infrared absorption measurements to glasses because this method responds to forces rather than to distances. J. Zarzycki and F. Naudin[23] investigated the structures of some simple glasses by this method and they could answer a question which in the minds of some scientists has not yet been answered adequately, namely, the justification of the ionic description of glasses.

Zarzycki and Naudin measured the forces which are active between the cations and their anions in vitreous $SiO_2$, $GeO_2$, and $BeF_2$ and found the following force constants (dynes/cm):

$$K_{Si-O} = 4.0 \times 10^5, K_{Ge-O} = 3.3 \times 10^5, K_{Be-F} = 1.1 \times 10^5$$

These three glasses have the same geometry but they are characterized by different forces. Taking the forces in $SiO_2$ as unity one finds those in $GeO_2$ to be

$$K_{Ge-O} / K_{Si-O} = 0.83$$

because of the larger Ge–O distance and those in $BeF_2$ to be only

$$K_{Be-F} / K_{Si-O} = 0.28$$

because of the smaller charges.

If these binding forces are essentially Coulombic forces they can be derived from the ionic charges and the interionic distances according to Coulomb's law.

Zarzycki and Naudin carried out these calculations on the basis of the interionic distances in Table III,

Table III

$r_{Si-O} = 1.60$ A.U.
$r_{Ge-O} = 1.70$ A.U.
$r_{Be-F} = 1.60$ A.U.

and found the ratios given in Table IV.

Table IV

$K_{Ge-O} / K_{Si-O} = 0.88$ (experimental: 0.83)
$K_{Be-F} / K_{Si-O} = 0.25$ (experimental: 0.28)

This close agreement between the experimental values and those obtained by calculations based on Coulombic forces justifies treating these glasses as consisting of ions.

The exact nature of the "randomness" of vitreous silica has been subject to much speculation but no definite picture has yet been proposed. The volume anomalies of vitreous silica at –80°C and the fact that vitreous silica when chilled from very high temperature has a smaller volume than an annealed specimen indicates the existence of some structural order. The solvent power of silica for hydrogen gas and for helium reveals the presence of some "holes" or "shrinkage voids." The Raman as well as the infrared spectrum of vitreous silica reveal forces which are weaker than those between $Si^{4+}$ and $O^{2-}$ ions or interactions between masses which are relatively large. The fact that silica heated well above the melting point of cristobalite may nucleate either quartz or cristobalite crystals depending upon the heat treatment reveals an order which must go beyond the individual tetrahedra.

Until we know more about the nature of the "randomness" or the degree of order beyond the $SiO_4$ tetrahedra we will continue to use B. E. Warren's description who himself called it a "first approximation" and we will refer to the long range order in vitreous silica simply as that of a "flawless" Bernal liquid for which the concentration of defects is very small.

## 2. The Structure of Alkali Silicate Glasses

According to our views, the introduction of alkalies into silica brings about changes in the distribution of binding forces and internuclear distances which cause the structure of the "flawless" liquid of the Bernal type to change in the direction toward the "fissured" liquid of the Frenkel model. We cannot expect, therefore, that the X-ray method which gives average values for Si–O distances, etc. can provide as good a picture for alkali silicate glasses as it did for vitreous silica.

As compared with silica the structure of an alkali silicate glass contains a certain number of "non-bridging" $O^{2-}$ ions in addition to the bridging ones.

With respect to its screening power a non-bridging oxygen is far superior to a bridging one. An $Si^{4+}$ ion interacts more strongly with a non-bridging than with a bridging $O^{2-}$ ion. When Zarzycki and Naudin measured the force constants of the two kinds of Si–O bonds they found that the non-bridging oxygens are bonded more strongly (20 per cent) to a silicon than the bridging ones. An alkali silicate glass containing a certain concentration of non-bridging oxygens will be more stable if the latter are evenly distributed producing what is called a superlattice in solid solutions of metals.

Workers in the field of glass technology are well aware of this phenomenon. The simplest way to account for deviations from a smooth property-composition curve was to assume the existence of compounds and a close relation between glass structure and the phase diagram (A. Winter[24]). No matter which terminology one prefers it seems obvious that the conventional description using the word "random" requires a drastic revision.

We consider the screening demands of the $Si^{4+}$ ions and also those of the alkali ions. The tendency of the alkali ions to surround themselves with non-bridging, better screening $O^{2-}$ ions can introduce a second principle which opposes randomness and which lowers the entropy on cooling. This ordering principle, in the extreme case, may lead to a segregation into regions of higher and lower concentrations of alkali. This tendency should be strongest for the $Li^+$ ions.

The addition of alkali affects the atomic structure of vitreous silica in four ways.

*(1)* The oxygen ratio, i.e., the number of all $O^{2-}$ ions divided by the number of $Si^{4+}$ ions, is increased.

*(2)* The alkali ions contrapolarize some bridging $O^{2-}$ ions. This weakens some Si–O–Si bonds by drawing electron density away from the binding region between two silicon cores toward the alkali ions. This effect

increases with increasing field strength so that $Li^+$ ions weaken the Si–O–Si bonds more than $K^+$ ions.

*(3)* A non-bridging $O^{2-}$ ion introduced into silica by $K_2O$ is more polarizable than one introduced by $Li_2O$. The more polarizable the non-bridging $O^{2-}$ ion the better will it screen its $Si^{4+}$ ion so that the latter interacts less with its bridging $O^{2-}$ ions. Through this interaction $K_2O$ weakens the Si–O–Si bonds more than $Li_2O$ and makes the whole structure more polarizable (increase of the molar refractivity).

*(4)* In their attempt to screen themselves preferentially with non-bridging $O^{2-}$ ions the alkali ions in particular the $Li^+$ ions introduce into the system a tendency to form regions of different compositions.

We see that the effect which alkali has on the forces within a glass and on its properties is much more complicated than one would expect from the conventional picture. Comparing the alkalies on a molar basis eliminates the oxygen ratio *1* as a variable. At high temperatures where the entropy effect minimizes the segregation into regions of different alkali concentration *4*, one still has to consider two major effects. These effects *2* and *3* are antagonistic so that it is not possible to predict in which direction the substitution of one alkali for another will change the viscosity.

Even if one assumes that the three alkali silicate glasses have the same distribution of the non-bridging $O^{2-}$ ions one cannot answer the question which of the three alkalies produces the glass with the lowest viscosity.

The work of K. Endell and H. Hellbrügge[25] reveals that indeed no definite answer can be given to this question. Molten alkali silicates with a low oxygen ratio (e.g., $<$ 30 mol per cent alkali) have viscosities which increase from lithium to sodium and potassium. However, the viscosities of the melts with a higher alkali concentration (e.g., 50 mol per cent alkali) increase from the potassium to the lithium silicate.

The effect of alkali upon the structure of silica can be described as follows:

The addition of alkalies to silica increases the oxygen to silicon ratio and with it the polarizability of all anions. The greater the polarizability of the $O^{2-}$ ions the lower will be the temperature at which a homogeneous liquid phase can exist. Because of its effect upon the polarizability of all $O^{2-}$ ions alkali, $K_2O$ more so than $Li_2O$, will increase the compatibility of other oxides with silica. The non-bridging $O^{2-}$ ions of high polarizability act as "flaws" because they are centers of asymmetry which cause a disproportioning of all binding forces. The addition of alkali shifts the structure of silica from that of a flawless liquid toward a fissured liquid. As centers of an asymmetry the non-bridging oxygens increase the anharmonicity of the thermal vibrations and with it the thermal expansivity.

Increasing the concentration of an alkali does not change all properties of a glass in a monotonic function because new symmetries (superlattices) can be established as the concentration of non-bridging $O^{2-}$ ions increases. Some properties such as the thermal expansivity of a glass are very sensitive to symmetry whereas others such as the molar refractivity are not.

No simple relation can be expected between field strength of the alkali ions and glass properties. Substitution of one alkali ion for another exerts antagonistic effects and the magnitude of the effects should be a function of the distribution of the alkali ions in the glass and their absolute concentrations.

The antagonistic effects which a change of the field strength of the alkali exert upon the distribution of binding forces are responsible for the fact that the substitution of one kind of alkali for another does not produce drastic changes in the properties. This in turn created the impression that the kind of alkali one uses for glass melting is not important. Alkali ions were described as playing only a minor role in the atomic structure of glasses. Their main function was to neutralize the charges of the non-bridging $O^{2-}$ ions which the alkali carbonates introduce.

If one wants to demonstrate the role which alkali ions play in the constitution of glasses one may add some nickel oxide to alkali silicate glasses. The lithium silicate turns yellow, the sodium silicate grey, and the potassium silicate turns deep purple. We described in greater detail in the Part III* of this series that $Ni^{2+}$ ions may participate in a glass structure both in fourfold (purple) and in sixfold coordination (yellow). In a sodium silicate glass an equilibrium between the two complexes is established. The coordination number of the $Ni^{2+}$ ions is a function of both the temperature and the polarizability of the $O^{2-}$ ions. Potassium oxide introduces into the glass $O^{2-}$ ions of greater polarizability than lithium oxide. Hence the potash glass favors fourfold coordination.

This situation should apply to all cations which occur in a glass in more than one type of coordination, e.g., $Ge^{4+}$ and $Ti^{4+}$ ions. Most important in this respect is the $Al^{3+}$ ion which like the $Ni^{2+}$ ion forms $AlO_4$ tetrahedra and $AlO_6$ octahedra. The paramount importance of the alkali for the atomic structures of alumino-silicate glasses can best be seen from the melting points of corresponding alkali alumino silicates.

Leucite, $K_2O.Al_2O_3.4SiO_2$, melts at 1680°C but the corresponding spodumene, $Li_2O.Al_2O_3.4SiO_2$, melts at 1423°C. Even more drastic is the difference between $Na^+$ and $K^+$ in the feldspars albite (M.P. 1118°C) and orthiclase (1533°C). The latter is of particular importance for the manufacture of ceramic products. Potash feldspar is used as a flux in whiteware bodies where it is desirable to have a liquid phase which has a very high viscosity. Soda feldspar, on the other hand, is used as an ingredient in glazes because it too introduces the desirable $Al_2O_3$ but without raising the viscosity of the glaze as much as potash feldspar. Carnegeite, $Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2$, melts at 1526°C and the potassium analogue melts around 1750°C.

*The Glass Industry, *41*, 687 (Dec. 1960), *42*, 23 (Jan. 1961), and 76 (Feb., 1961)

We attribute this difference in viscosities and liquidus temperatures of alumino silicates to the effect of the polarizability of the $O^{2-}$ ions upon the way in which the $Al^{3+}$ ions are screened. The melting point of orthoclase is closest to that of the cristobalite because the symmetry is highest if the melt consists of $SiO_4$ and $AlO_4$ tetrahedra. Albite has a lower melting point and its melt is less viscous because of the asymmetry which the $AlO_6$ groups introduce into the array of $SiO_4$ tetrahedra.

### 3. The Structure of Alkali Borate Glasses

Vitreous silica because of its "flawless" structure permits us to correlate some of its properties with the average Si–O bond strength. The addition of alkali to silica changes all binding forces and as a result of the new distribution of binding forces the average Si–O bond strength has lost physical reality and is no longer useful for describing the forces acting within the glass. Boric oxide glasses even when free of alkali have complex structures for which the average B–O bond strength has no physical meaning and cannot be used as a parameter regardless of whether this value has been derived from the field strength of the $B^{3+}$ core or from the heat of formation of the oxide from the atoms. Nobody would think of characterizing a polyethylene by an average bond strength. A determination of the structure of $B_2O_3$ glasses by H. Richter, G. Breitling and F. Herre[26] reveals that the $B^{3+}$ core forms the apex of a low tetrahedron the base of which consists of three $O^{2-}$ ions. This structure might be interpreted as "boron in threefold coordination"; however, a three-dimensional structure calls for at least one more $O^{2-}$ ion to screen the $B^{3+}$ core in the direction opposite to the basal triangle.

We prefer the concept that a boric oxide glass has a complex structure corresponding to that which G. Hägg[27] gave of a glass-forming liquid. The response of $B_2O_3$ glass fibers to X-rays and to magnetic fields justifies a comparison of its structure with that of an "orientable" liquid. We see no justification for looking upon a change of coordination of the $B^{3+}$ core as the cause of the difference between $B_2O_3$ and $SiO_2$ glasses and their derivatives. It is possible that the ability of $B_2O_3$ to polymerize and to show orientation when stretched may be connected with the shape of the $BO_3$ pyramids. Boric oxide forms a liquid at relatively low temperature which owes its reluctance to nucleate to its complexity. In Part II of this series we listed in greater detail some structural units occurring in vitreous $BO_3$ as they were suggested on the basis of specific heat measurements, Raman spectra, etc., but these details are mainly of academic interest. We consider that it is the complexity of the structure of a $B_2O_3$ glass which is responsible for the unusually strong effect which the thermal history has on its properties.

For the interpretation of the properties of alkali silicate glasses we pointed out that the formation of non-bridging oxygen ions introduces centers of asymmetry into vitreous silica. This concept does not apply to alkali borates because in contrast to $SiO_2$ vitreous $B_2O_3$ itself consists of asymmetrical units. As far as the distribution of binding forces is concerned vitreous $B_2O_3$ resembles organic high polymers which are characterized by strong forces within and weaker forces between the molecules.

The conventional explanation of the atomic structure of alkali borates and the change of their properties with increasing $Na_2O$:$B_2O_3$ ratio is based on a very improbable assumption, namely, a reversal of the coordination number of boron. It has been suggested that the addition of alkali up to a certain concentration causes the $BO_3$ triangles to change into $BO_4$ tetrahedra. Beyond this critical concentration, however, further additions were supposed to bring about the opposite change, namely, lowering the coordination number from 4 to 3. We do not agree with this explanation for two reasons. Firstly, the coordination number of boron has little meaning unless one deals with symmetrical units such as $BF_3$ triangles and $(BF_4)^-$ tetrahedra. Secondly, the addition of alkali to $P_2O_5$ causes changes similar to those in borates and it is not likely that the $P^{5+}$ core changes its coordination of four. A change of the $AlO_4$ tetrahedron to an $AlO_6$ octahedron affects the properties of a glass but apparently no corresponding change takes place in borate glasses.

When discussing the use of color indicators (Part III) we pointed out that the average coordination of the $Ni^{2+}$ or $Co^{2+}$ ion decreases if more polarizable $O^{2-}$ ions are introduced. If the $B^{3+}$ core would participate in the structure of vitreous $B_2O_3$ in the same way as $Ni^{2+}$ or $Al^{3+}$ ions it becomes illogical to assume that increasing additions of alkali first increase and later decrease its average coordination number. We look upon the first additions of alkali as causing a profound change in the liquid structure. The alkali ions break up the polymers and change the orientable liquid in the direction toward one which corresponds to either the "flawless" (Bernal) or the "fissured" model (Frenkel).

Additions of alkali to vitreous $P_2O_5$ bring about similar changes in the properties and, in the case of $P_2O_5$-$Na_2O$ glasses, we can be sure that the $P^{5+}$ core does not change its coordination. Analogous to the borates, the alkali phosphates as well as the arsenates and vanadates have higher melting points than the oxides.

This structural change which occurs in $B_2O_3$ upon the addition of $Na_2O$ can be plotted in our liquid structure scheme (Fig. 1). As high temperature favors the formation of fissured structures more than of flawless structures we assume that the route by which the structural change takes place depends upon the temperature. Using the viscosity data of L. Shartsis, W. Capps, and L. Spinner[28] as the basis for our reasoning we may say that at 1000°C and above, the addition of $Na_2O$ to $B_2O_3$ changes the structure of the glass toward that of the "fissured" liquid. At lower temperature the addition of alkali changes the structure first toward that of

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the "flawless" liquid, i.e., the viscosity increases. Only if more alkali is added does the structure change toward that of the fissured liquid.

In contrast to silicon which requires fourfold coordination, the $B^{3+}$ core because of its smaller size and its helium configuration can be screened by three anions. The compound $BF_3$ is a gas at ordinary temperature. Hence, $B_2O_3$ has a lower melting temperature than $SiO_2$ in spite of its lower anion to cation ratio. The $P^{5+}$ core has the same electron configuration as the $Si^{4+}$ core. Hence we must attribute the lower melting temperature of $P_2O_5$ as compared with $SiO_2$ to its greater anion to cation ratio.

It is important for the glass technologist to realize that the oxides $B_2O_3$ and $P_2O_5$ have low melting points for very different reasons. Therefore, the apparent similarity which exists between these oxides and the alkali borates and phosphates disappears if $B_2O_3$ and $P_2O_5$ are introduced into silicate glasses. When added to an alkali silicate glass, $B_2O_3$ increases the symmetry of forces but $P_2O_5$ adds more non-bridging oxygen, thus shifting the atomic structure of a sodium silicate closer toward that of the fissured model.

## V. CONCLUSIONS AND SUMMARY

The formation of a glass is based on the supercooling of a homogeneous liquid. The liquid state is the one essential condition for glass formation which cannot be bypassed. The rapid condensation of vapors on cold surfaces or the extreme mechanical deformation of crystals or their neutron bombardment can produce amorphous solids but those solids have a chaotic structure and they are not glasses.

In order to systematize the atomic structures of liquids a scheme has been developed which uses three extreme models, namely, those suggested by Bernal, by Frenkel, and by Stewart.

The first model (Bernal) can be called a "flawless" liquid because deviations from regularity are only minute. This model can portray a liquid if the temperature is such that the binding forces are overcome by the thermal motion or the kinetic energy. This liquid has a high viscosity just above the melting point of the substance and on cooling it can form a stable glass (vitreous silica, albite glass).

The second model (Frenkel) is another extreme and can be called a "fissured" liquid. A fissured liquid bears no resemblance to the crystal from which it has formed. Even just above the melting point such a melt is very fluid because of the rapidity with which fissures form. This type of liquid, e.g., fused NaCl, cannot be supercooled to form a glass. In a fissured liquid the kinetic energy has to overcome only the weakest and not the average binding forces.

The third model (Stewart) is one which shows some regularity because it contains permanent molecules (organic polymers) or semipermanent structural units (helical sulfur fibers, chain-like polyphosphate anions, rings, etc.). Glass formation from such a complex liquid is possible. The structural units can be oriented, if the liquid flows or the glass is drawn into a fiber. Glass fibers formed from this type of liquid (sulfur, sodium phosphate, boric oxide) can be distinguished from glasses which have formed from a flawless liquid because their X-ray patterns and their diamagnetism reveal orientation and anisotropy. This type of liquid was called an "orientable" liquid. As in the fissured liquid no relation can be expected to exist between the average binding forces and the kinetic energy which is necessary to change a crystal into an oriented liquid.

Using these three extremes as references, one can describe structural changes in glasses by a scheme based on a ternary diagram which includes all possible intermediate liquid structures.

Any liquid the structure of which is close to the model of a fissured liquid crystallizes on cooling. If the temperature is raised the structure of any liquid approaches that of the fissured liquid. A chilled glass has a structure which lies closer to the corner represented by the fissured liquid than the same glass in annealed condition. Addition of alkali to silica moves the structure from the flawless liquid toward the fissured liquid. The first additions of alkali to boric oxide moves the low temperature structure of the glass from the corner representing the orientable liquid toward that representing the flawless liquid. Larger additions of alkali change the structure toward the fissured liquid. In the high temperature region ($> 1000°C$), however, the addition of alkali changes the structure of $B_2O_3$ directly toward that of the fissured liquid.

Glasses as supercooled liquids have structures which can be described as a superposition of three extremes. The ability of a liquid to form a glass is inversely proportional to the fraction or the "concentration" of the "fissured" structure. Glasses which have a large fraction of the orientable structure are less brittle than those which resemble closely the "flawless" structure. Amorphous organic high polymers (orientable structure) resemble $B_2O_3$ in their mechanical properties more than silicate glasses. The description of $B_2O_3$ as tough rather than brittle[29] supports our grouping together boric oxide glasses and organic high polymers. The addition of alkali to $B_2O_3$ produces a greater symmetry in the distribution of binding forces so that the resulting glass is more brittle.

We found that there is no justification for assuming that a tetrahedral structure is essential for glass formation. We found it advantageous to emphasize the forces rather than the geometry as revealed by X-rays. A non-bridging oxygen in an alkali silicate glass represents a center of an asymmetry because its state of polarization is very different from those of the binding oxygens. The fact that a non-bridging oxygen is a better screener

(*Continued on page* 221)

# Bibliography on Glass Structure*

## PART X

**283. P. W. Bridgman and L. Simon**

"Effect of Very High Pressures on Glass," J. Appl. Phys., 24 (4) 405-13 (1953); Cer. Abs., 36, 168g (1953).

Glasses may be permanently compacted by pressures of $10^4$ to $10^5$ atm. This effect was studied on two simple oxides ($SiO_2$ and $B_2O_3$) and several silicate glasses by measuring densities, dimensions, and x-ray diffraction patterns. A definite threshold pressure was observed in vitreous $SiO_2$ and silicate glasses below which no effect takes place and above which collapse takes place readily. Vitreous $B_2O_3$ collapses gradually, starting at the lowest pressures; it also shows plastic flow with subsequent strain hardening. X-ray study showed that compacting proceeds on the atomic scale, leaving the nearest neighbor distance of Si--O or B--O, however, approximately unchanged. Consequently, the mechanism of compacting is some kind of folding up of the vitreous network, involving bending rather than shortening of Si--O or B--O bonds. Annealing will restore the density of compacted glass if the temperature is raised sufficiently. The activation energy of this process was determined for vitreous $B_2O_3$. With an increasing amount of added Na the capacity for permanent deformation with change of shape increases. The apparatus used is described. II figures, 6 photos.

**284. R. W. Brill**

"Experimental Determination of Electron Distribution and Bond Type in Quartz and Related Compounds," Ceram. Age 61 (3) 33-34, 36 (1953).

The two extreme types of chemical bond are the ionic and the covalent. In the ionic type, the forces between the different atoms of a compound are electrostatic; in the covalent type, the atoms of a molecule are held together by means of quantum-mechanical exchange forces. The main difference between ionic and covalent bonds lies in the arrangement of the electrons. The strong participation of both bond types in the case of $SiO_2$ seems to be responsible for the formation of stable charged macromolecules in derivatives of silica. The $SiO_4$ tetrahedra which are found isolated in orthosilicates can be connected by sharing oxygen atoms. In this way, chain molecules (as in asbestos), two-dimensional networks (as in mica), or three-dimensional networks (as in mica), or three-dimensional networks (as in quartz) can be formed. Since the forces between silicon and oxygen are stronger than the normal ionic forces, the form of the agglomerate of $SiO_4$ tetrahedra, whether chains, planar, or three-dimensional networks, primarily determines the physical properties of these substances.

**285. B. Daragan**

"Derivation of Annealing Curves from the Theory of Glass Structure," (Univ. cathol., Louvain, Belg.). Verres et refract. 7, 157-66 (1953); of C. A. 46, 8339i.

From experimental data of stepwise glass annealing, and on the basis of the theory of structural changes in glass in the annealing range, A. Winter (1938) derived an ideal (called "classical") curve for the annealing process. In practice, it is generally assumed that d. changes correspond to these structural changes, and with a method given by Preston, ds. are determined for the control of the annealing process. Daragan studied these interrelations for 2 crown glasses (AN and B 0061) and one borosilicate crown glass (B 1864), over a temperature range which extends from 100° above the dilatometric transformation point ($0_{tr}$) to 50° below it. The cooling schedule for the determinations was chosen (I) following the "classical" continuous curve of A. Winter (C.A. 40, 7544[5]), (II) in stepwise cooling in 10° steps, and (III) stepwise cooling with 5° steps. The time conditions for producing in the final state of optical glass samples a birefringence of practically zero are discussed as functions of these cooling schedules. There is a distinct and considerable decrease of time required for annealing to complete stabilization, if the stepwise process is adopted, especially for III; the required time is reduced in comparison to III with I by 61% in glass B 0061, by 50% for B 1864, and by 39% for glass AN. The end state of stabilization with a minimum residual birefringence is obsereved at an end temperature, $T_1$, which must be 40 – 50° below $0_{tr}$; from $T_1$, the final cooling can be done rapidly, e.g. in 15 minutes to room temperature. A curve for practical annealing is given which demonstrates the percentage of (partial) stabilization as a function of the percentage of time required for total stabilization. From this curve it is easy to derive the type of a special thermal treatment of a given glass, with a tolerable approximation to total stabilization.

*(To be continued in May)*

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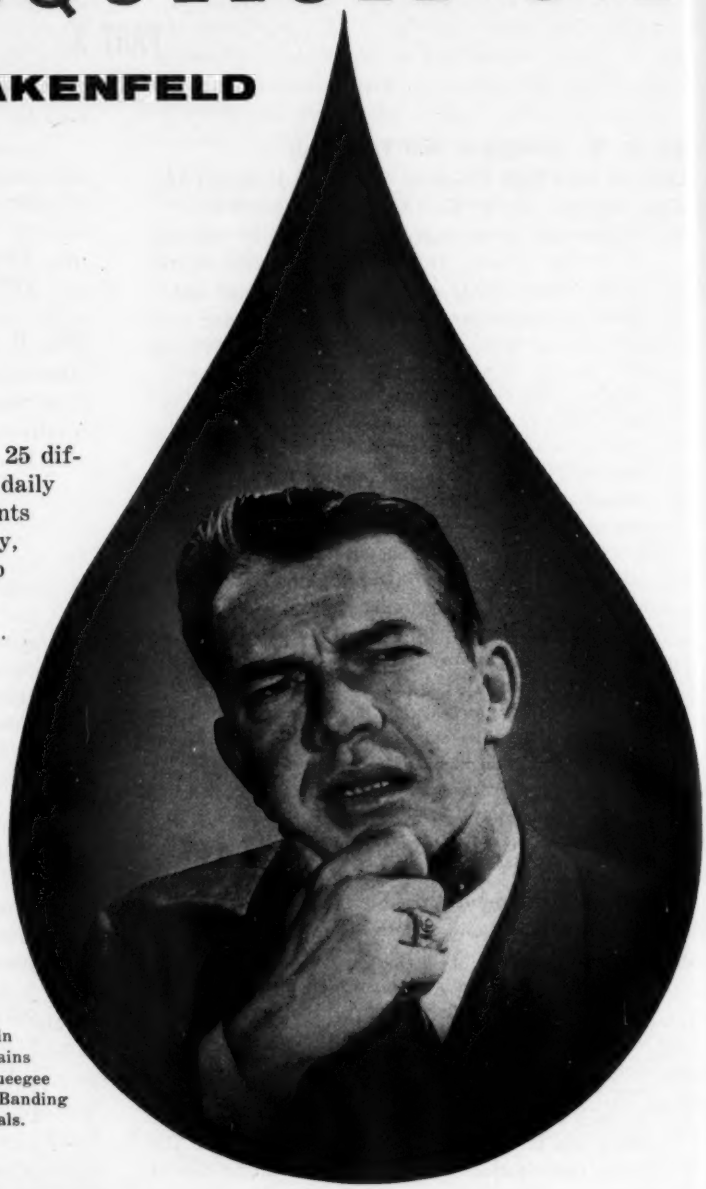

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*by Herman J. Troche*
Vice-President and Consultant, Holan Corporation, Cleveland, Ohio

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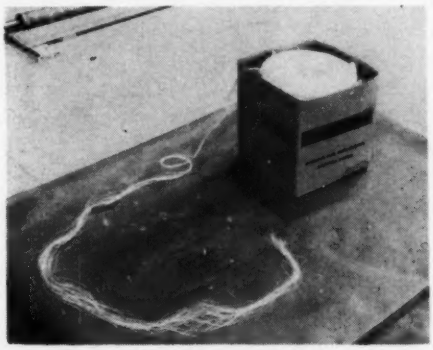

Fig. 2. Fiber glass roving for use with fiber-resin depositor.

Essentially, the feasibility of working barehanded on highly energized electrical conductors depends upon one of the materials employed in the makeup of an aerial boom and work basket which operate to elevate linemen to their work area, and to hold them in a convenient position there. To be safe while in contact with and working on an energized electric conductor, the workmen must be completely insulated from the ground and other conductors. The necessary protection from ground is provided by the use of fiber glass in this boom and in the special work basket which it supports. All control rods connected to the basket are also made of fiber glass.

To be suitable for this application, the material selected must have good electrical and physical properties. Dielectric strength is required to protect the workman with good insulation if he comes within close proximity of one phase or ground while he is working on another phase. Good physical strength is essential to provide a safe perch without excessive weight in the overhanging boom members. Both of these are found in good measure in fiber glass.

Assurance that the dielectric strength of each work basket complies with specifications is gained by subjecting it to an immersion test in which a 72,000-volt dc current is applied and maintained inside the basket for a one-minute period. All work baskets must pass this test successfully before they can be used on an aerial boom. Additional tests have been performed on sample panels of laminate of the same construction and manufacture as the walls of the work baskets, with findings of dielectric strengths in excess of 500 volts per mil.

Fig. 1. Men in specially screened work baskets on the aerial elbow are working bare-handed while installing a repair sleeve on an energized conductor where line voltage is 138,000 volts. The repair was made without service interruption.

In addition to exacting electrical tests of these parts, their physical properties are checked periodically in tests carried on to the destruction of the test piece. The data collected reveals a safety factor of approximately 5 to 1 when the ultimate stress at failure is compared to the 2000 psi fiber stress of the boom section at maximum rated load.

The sides of the work basket on the aerial elbow flare outward from top to bottom (a feature patented by Holan), thus making toe room for the workmen while they stand in the basket, leaning against the side for support. A full-width step is also built integrally into the outside wall, providing a convenient means for entry and exit. Although both of these features do much to improve the utility of a work basket, the resulting shape of the basket makes the use of many materials economically impractical. For this application, a material which can be easily shaped or molded is necessary. Furthermore, it must possess good physical properties without excessive weight, and sufficient dielectric strength to insulate the workmen against energized conductors. Fiber glass meets these specifications in that its physical makeup can be compounded to fit exacting manufacturing procedures and performance requirements.

The methods used in the fabrication of the boom and

Fig. 3. The greater part of the fiber glass and resin are deposited and rolled out while the mold is open.

Fig. 5. Clamping two halves of mold together prior to laying lamina e over joint in mold.

work baskets are quite different. The boom section is square and tubular in shape. It is fabricated by wrapping a woven fiber glass roving—saturated with a polyester resin—around a square mandrel. While the woven roving is being wrapped on the mandrel, the excess resin is rolled and squeegeed out so the finished laminate will have a high glass content necessary for good tensile and flexural strengths.

To produce the work basket, a wood pattern is matched to the outside contour and size of the basket. The molding surfaces of this pattern are polished, waxed, and covered with a coat of gelcoat. After the gelcoat has set up, the laminate is laid up and left on the pattern until cured. After removal from the pattern, the inside of the mold is polished to a high luster to provide for a smooth exterior surface on finished baskets. A generous coat of wax is applied and rubbed out on the inside of mold. The mold is then ready for use in the fabrication of the work baskets by the spray-up method.

Here a fiber-resin depositor is used. Chopped strands of glass roving are hurled from a cutter on the depositor into the path of twin sprays of catalyzed and accelerated resin before being deposited into the mold. A hand roll-out operation removes the trapped air and provides a laminate of suitable physical and dielectric strengths.

Fig. 4. Closing mold with rolled out laminate in each section.

It is important that both the glass fibers and the polyster resin are of the type that wet out easily because of the hard-to-get-at places inside the closed mold. In addition to the rapid wet out, the resin must have a low viscosity and good thixotropic properties to prevent drain out before the gel cycle takes place.

In the final phase of the molding operation and during the curing cycle, the mold is laid on its side in a fixture. While in this position, the basket floor and two of the side walls are in a nearly vertical position, with one side wall practically overhead. Here it can easily be seen why a resin with special properties is required.

After the laminate has cured at room temperature it is removed from the mold and given a postbake in an oven. The tackiness which exists at the end of the room cure disappears during the postbake, and insulation properties are improved. After the baskets have passed the electrical test they are mounted on the support shaft at the outer end of the aerial elbow arm. Control levers positioned on the basket support shaft remotely control the operation of a hydraulic valve located on the main mast. While in the work basket, the operator can control all the elbow movements necessary to station him in innumerable working positions.

Plain work baskets are supplied on aerial elbows used in general line maintenance, tree trimming, and street light service. The aerial elbows to be used for the barehanded method of live-line maintenance are supplied with metal shielding inside the work baskets, and with other accessory equipment required to make them suitable for this type of service. Despite the fact that adequate shielding is provided, this revolutionary method of live-line maintenance should be performed only by personnel who have been properly trained.

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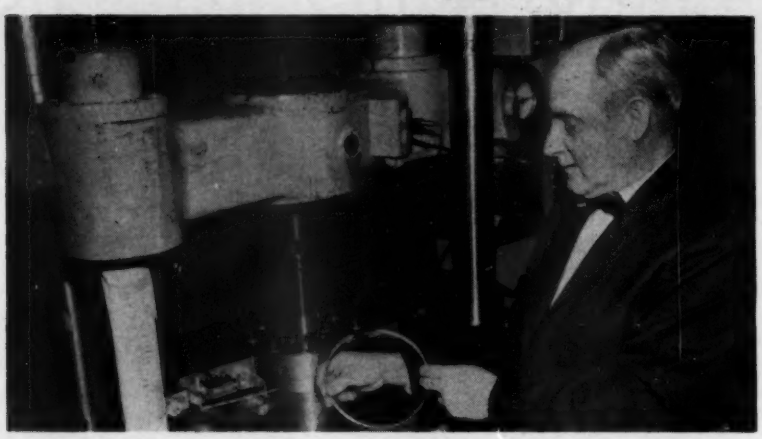

NOL chemist, Dr. Porter W. Erickson, examines a "NOL Ring" which he has just ruptured with the tensile tester. He shares credit for developing the tester with F. Robert Barnet, H. A. Perry, Hyman Kessler, and Virgil Milani, all of NOL's chemistry research department, nonmetallic materials division.

LIGHT-WEIGHT FIBER GLASS ROCKET MOTOR CHAMBERS reinforced with nonwoven glass fiber (roving) will soon be standard equipment for space vehicles according to chemists at the Naval Ordinance Laboratory in Silver Spring, Md. They may cost only a fourth as much as metal chambers presently in use, and be up to three times as strong on a weight basis.

A test device for studying fiber glass, called the "NOL Hydraulic Ring Tensile Tester," is being used to develop a body of quality control data needed to define more precisely the strength and environmental resistance properties of parallel glass filament for reinforcing plastics. This data will ultimately be employed in the preparation of specifications for glass roving for plastics reinforcement.

The tensile tester is essentially a pressure-tight housing in which fiber glass test hoops are hydraulically ruptured, thus determining their tensile strength and modulus of elasticity. Resulting data is in many cases directly applicable to the design of large rocket motor chambers, the shapes of which are similar to those of the hoops.

Known as "NOL Rings," these hoops were designed at the laboratory specifically for the tensile tests. They are fabricated by drawing glass strands through a resin bath onto a circular mold under controlled conditions of temperature, tension, and wind angle. Testing with the "NOL Rings" has so far indicated that the application of a chemical finish to glass fibers is one of the important factors in improving the tensile strength of a glass reinforced plastic.

Plastics reinforced with parallel glass fiber have gained wide-spread scientific interest because they offer the engineer a means of controlling the directional strength of a structural item to a degree not possible with woven fabric or random mat fiber glass. Furthermore, parallel glass fibers can theoretically be packed to occupy over 90 per cent of the volume in a reinforced plastic, a distinct advantage over mat fiber glass because the strength of a reinforced plastic is directly proportional to its glass content. *U. S. Naval Ordinance Laboratory.*

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FIBER GLASS PANEL with steel strips imbedded within its translucent surface has been designed for decorative applications where leaded glass is normally used. The panels are produced in crystal green or clear colors and measure 24" x 96". The strip patterns within the panels are available in a diamond or shell design colored in either gold or steel.

The panels are labeled "Lead Glass" and they can be used as screens, room dividers, doors, tops for lawn or porch furniture, breakfronts, storm doors, shower stalls and tub enclosures. They are shatterproof, acid and moisture resistant, will not stain, and can be wiped clean with a damp cloth or sponge. *Barclite Corp. of America.*

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FIBER GLASS SAFETY PLATFORM LADDERS which are nonabsorbant and do not conduct electricity have been desiged for use around high voltage. Steps and platform are of nonslip construction, and the top of the ladder, which resists the effects of moisture, chemicals, acids, and corrosive fumes, serves as a safety rail. *Aluminum Ladder Co.*

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FIBER GLASS RESILIENT PADS are used to provide a cushioning for solid propellant combustion chambers in missiles.

When the solid propellant grain expands in warm weather the padding absorbs the expansion, thus keeping the grain intact, and not permitting it to crack. Due to its high coefficient of thermal expansion the propellant contracts rapidly in cold weather while the padding expands, thus eliminating looseness in the grain which would lead to cracks resulting from vibrational and shock loads.

The pads are generally molded into flat or contoured shapes which are placed at one or both ends of the grain. The spring rate is controlled by varying density. The typical stiffness in a medium density produces a load of 25 psi at 50 per cent deflection. The pads also absorb launching shocks and G-loads. *Fibrous Glass Products, Inc.*

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# NEWS
## IN THE GLASS INDUSTRY
### Personalities...

Harold W. Baque

Benjamin P. Colosky

John M. Rauscher

**Harold W. Baque**
Vice-president and assistant to the president, Corhart Refractories Co., and John K. Meyer, vice-president and general sales manager.

John R. Meyer

With the firm since 1930, Baque has been serving as a vice-president and manager of glass refractory sales. In his new capacity, he will focus on Corhart's international business.

Edward E. Humphry

Meyer joined the company in 1938, and in 1955 was named a vice-president. He was made manager of metallurgical sales in 1957, and will now coordinate all sales of the company.

Edward E. Humphry has been promoted to field sales manager and Benjamin P. Colosky to staff sales manager. John M. Rauscher becomes manager of technical services.

**Frank W. Trost**
District manager of the Philadelphia sales territory, The Chas. Taylor Sons Co. With the firm since 1950, he will make his headquarters at the district sales office in Haddonfield, N. J.

Frank W. Trost

**Donald E. Emhiser**
Technical advisor, Pittsburgh Plate Glass Co.'s glass division, with headquarters in the firm's Pittsburgh general office. He succeeds Joseph S. Gregorius who retired March 1 after 37 years of service with the company.

**James C. Laughrey**
Sales engineer, O. Hommel Co., wit headquarters at the Pittsburgh hom office. Formerly associated with th Shenango China Co., he will assum

James C. Laughrey

the duties of Harry L. Barker, who has left the firm to establish his own business.

**William J. Meinel,**
John Mulford, Esq., and Gerry Swinehart elected to the board of directors, Selas Corp. of America. Meinel is chairman of the board, Heintz Mfg. Co., Mulford, a partner of Drinker, Biddle, and Reath, Philadelphia, and Swinehart, chairman of the board, Carl Byoir & Assoc., Inc., New York.

**Joseph F. Greene**
Retired February 28 as manager of customer research for the blown and tube division, Kimble Glass Co.

### T. Earl Markwell

Industrial sales manager, Virginia Mirror Co. A veteran of 25 years experience in the mirror industry, he has been with the firm since 1951, most recently as divisional sales manager for the eastern United States.

T. Earl Markwell

### Raymond A. Ashlock

To manage Owens-Illinois Glass Co.'s 46,000-sq. ft. mold shop, now under construction in Durham, N. C., and scheduled for completion this summer.

Raymond A. Ashlock

Prior to this assignment, he was superintendent of the mold shop in Alton, Ill., where he has served in various capacities since 1939.

Succeeding him at Alton is Harold V. Schlobohm, former supervisor of television and special products molds there.

### Dr. John F. G. Hicks

Named technical director, Corning Glass International, in conjunction with an expansion of the firm's scientific and technical activities. In addition to providing technical assistance to the company's manufacturing associates board, he will establish a program under which Corning will be able to benefit from technological advances occurring around the world.

### Dr. S. Frank Cox

Director emeritus of glass division research since 1956, Pittsburgh Plate Glass Co., has retired following 30 years of service. The author of several articles for technical and professional journals and, he has been awarded 30 patents since he joined the company in 1915.

Dr. Frank S. Cox

Cox became a research engineer in 1937, and in 1940, was made technical director, double glazing. In 1943 he was appointed director of research, a position which he held for 13 years before being named as the glass division's first director emeritus of research.

### Stephen Heller

Director of engineering, and Scott A. Musselman, manager of purchasing and traffic, Glascote Products, Inc., Cleveland, a subsidiary of A. O. Smith Corp., Milwaukee.

Robert Adamson

### Robert Adamson

Managing director, Consolidated Glass Works Ltd., Germiston, Transvaal, will retire from that position, which he has held for the past ten years, as of June 30, 1961. Adamson has been active in the glass industry for 51 years, 35 of which he spent in South Africa.

### J. T. Pitts

Sales manager, Minneapolis-Honeywell Regulator Co.'s Brown Instruments Division. He succeeds J. A. Robinson, who has joined the firm's 6-division industrial products group to coordinate expanding activities in metals-producing areas.

J. T. Pitts

J. E. MacConville has been appointed sales coordinator for the company's special systems division, with Fred B. Akerson succeeding him as regional sales manager in Atlanta.

### Dwight F. Partell

District manager, Pittsburgh Corning Corp.'s San Francisco office. Formerly sales representative to the western states, he will continue to have his headquarters at Orinda, Calif.

### Dr. Robert Gardon

In the newly-established position of research manager, Ford Motor Co.'s glass division, with headquarters at Lincoln Park, Mich. Formerly a member of the basic engineering research group at Pittsburgh Plate Glass Co., he has been active in the field of glass research since 1954.

Dr. Robert Gardon

### American Nepheline Ltd.

Has disclosed plans for expansion from the production of nepheline syenite into the broader field of industrial materials. The company, a wholly-owned U. S. subsidiary of American Nepheline Corp., Columbus, O., is asking its shareholders at the annual meeting to approve a change of name to Industrial Minerals of Canada Ltd., and a recapitalization which will give present shareholders one new share for ten old shares. New capital will involve 1,000,000 shares, only 410,000 of which will be issued.

### Owens-Illinois Glass Co.

Has announced its first general increase in bottle and jar prices since 1957, effective on shipments made April 1. Rising labor costs, fuel, transportation rates, construction, other costs including that of mold manufacture, and sharp drops in profit margins have been cited as reasons for the price increase.

### Rail Rates on Window Glass

Shipped from southern points to destinations in South Dakota were found unjust and unreasonable by the Interstate Commerce Commission, with reductions of between $124 and $357 on carloads transported to Aberdeen from Henryetta, Okla., Fort Smith, Ark., and Shreveport, La., resulting.

### Tarrif Commission Hears LOF, PPG on Flat Glass

George P. MacNichol, Jr., president, Libbey-Owens-Ford Glass Co., and Robinson F. Barker, vice-president and general manager, Pittsburgh Plate Glass Co.'s glass division, testified last month before the U.S. Tariff Commission, pointing out the hardships in the U.S. flat glass industry resulting from the high percentage of flat glass imports.

Thirty-seven per cent of LOF's window glass making capacity and 22 per cent of its window glass workers are idle, according to MacNichol, who pointed out that rising costs of manufacture—particularly wage rates—and greatly reduced import duties had prevented the company from meeting foreign prices. The company's average wage rates, including most fringe benefits, rose to $3.67 per hour in 1960 in comparison with foreign window glass manufacturing wages which range from one-tenth of LOF's rate in Japan to one-fourth in Western Europe.

Foreign imports of sheet glass amounted to 32½ per cent of total domestic shipments last year, Barker said, as compared to the ratio of imports to total domestic shipments in 1955 (about 15 per cent) and in 1958 (27 per cent).

He emphasized the cost advantages that foreign producers have over United States manufacturers which are reflected in drastically low prices in this market, the amount of price cuts ranging from 8 to 12 per cent by Western European producers, and from 13 to about 19 per cent by Japanese manufacturers.

Barker made it clear that Pittsburgh Plate was not asking the Tariff Commission to help in solving any sheet glass problems derived from economic recession, labor problems, or heavy capital expenditures on improved plants and equipment. Rather, he limited the need for effective relief to the sizable imports of foreign sheet glass into the United States market which have been the result, in whole or in part, of successive reductions in the applicable tariff duties. He reported that in no year since 1956 has Pittsburgh Plate Glass Co. operated its sheet glass factories at anywhere near 80 per cent of capacity, the minimum goal President Kennedy recently set as representing the basic incentive for the investment of new capital in manufacturing expansion necessary to economic recovery and growth.

In contrast, Barker said that Pittsburgh Plate Glass Co. sheet glass factories are now operating at 60 per cent of capacity, and the number of unemployed PPG sheet glass workers represents 25 per cent of its normal complement.

According to LOF's MacNichol, "Foreign manufacturers, with their tremendous advantage in labor costs, are able at any time to set their prices at levels enough below domestic prices to get the business. Our recent experience proved the utter futility of trying to meet prices established by foreign producers.

"We operated our window glass section at a loss, in 1960," he continued. "We have been forced to defer a planned 10 per cent expansion in window glass capacity which was intended to match the growth of the over-all U.S. economy."

"If LOF's idle men and machines were working, we could produce 110,000 additional tons of window glass per year. This compares with 203,000 tons imported into the U.S. in 1960. If the idle men and machines of other domestic window glass manufacturers were also working, the added tonnage would far exceed the tonnage now being imported."

Mr. MacNichol concluded by asking that the Tariff Commission recommend to President Kennedy the maximum possible relief under the law.

FINANCIAL DATA
(End Fiscal Year)

**Pittsburgh Plate Glass Co.**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 44,096,000 | $ 47,631,000 |
| Net Sales | $606,947,000 | $627,965,000 |

**American Potash & Chemical Corp.**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 5,149,755 | $ 5,157,859 |
| Net Sales | $ 54,621,189 | $ 50,546,003 |

**Foote Mineral Co.**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 1,146,786 | $ 534,432 |
| Net Sales | (Approx. same as 1960, excluding $3,422,000 delivered early in the year in completion of an A.E.C. contract.) | $ 16,614,013 |

**General Refractories Co.**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 4,517,849 | $ 4,470,542 |
| Net Sales | $ 56,135,426 | $ 62,910,794 |

**Vitro Corp. of America**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 565,252 (before special charges of $1,476,663) | $ 723,411 |
| Net Sales | $ 60,301,229 | $ 58,118,193 |

**Wyandotte Chemicals Corp.**

| | 1959 | 1960 |
|---|---|---|
| Net Earnings | $ 4,501,545 | $ 4,880,933 |
| Net Sales | $ 93,893,798 | $ 97,023,724 |

**Design Engineering Conference**

Topics scheduled for the May 22-25 Design Engineering Conference to be held at Cobo hall, Detroit, include "Glass, Ceramics, and Glass-Ceramics, Types and Properties" and "Design of Components Made of Glass or Ceramics." The conference and show are sponsored by the machine division of the American Society of Mechanical Engineers, and will feature exhibits from more than 400 companies producing materials and components for virtually every type of product manufactured in the country.

**Ford Motor Co.'s Glass Division**

Has established a new technical center in Lincoln Park, Mich., consolidating all company glass research and development activities there.

**Vitro Corp. Sells Berkshire**

Malcom H. McAllister, president of Berkshire Chemicals, Inc., a wholly-owned subsidiary of Vitro Corp. of America, has acquired that company from the parent corporation. Purchase of the firm, importers and exporters of industrial and agricultural chemicals, nonmetallic minerals, and ores, was effective March 1.

## 63RD ANNUAL A.C.S. MEETING*

## Glass Division Program

1. **Sintered Ceramics, Glass-Ceramics and Glass Comparison of Characteristic Properties and Microstructure.** S. D. STOOKEY, Corning Glass Works, Corning, N. Y.
2. **Crystallization of a Titania-Nucleated Glass.** R. D. MAURER, Corning Glass Works, Corning, N. Y.
3. **Catalyzed Crystallization in Glass.** WERNER VOGEL and KLAUS GERTH, Schott & Gen., Jena, Germany.
4. **Anomalous Changes in Elastic Moduli and Refractive Indices of Some Borosilicate Glasses as the Result of Heat Treatment.** EDGAR H. HAMILTON, National Bureau of Standards, Washington, D. C.
5. **Effect of Heat Treatment on the Strength and Abrasion Resistance of a Glass-Ceramic Material.** M. WATANABE, R. U. CAPORALI and R. E. MOULD, Preston Laboratories, Butler, Pa.
6. **Crystallization of a Lead Metaniobate Glass.** R. C. ANDERSON, University of Illinois, Urbana, Ill.
7. **An Unusually Refractory Partially Crystalline Vanadia-Silica Glass.** S. D. BROWN and S. S. KISTLER, University of Utah, Salt Lake City, Utah.
8. **Conditions of Glass Formation Among Simple Compounds.** W. A. WEYL, Pennsylvania State Univ., University Park, Pa.
9. **The Role of Phase Equilibrium Considerations in Crystallization Studies of Glasses.** RUSTOM ROY, Pennsylvania State University, University Park, Pa.
10. **Processes of Diffusion and Formation of Bubbles During Crystallization and Remelting of Crystals in Glass.** G. PECRIAUX and E. PLUMAT, Union Verreries Mechaniques Belges, Charleroi, Belgium.
11. **Crystal Nucleation by Glass in Glass Separation.** S. M. OHLBERG, H. R. GOLAB, and D. W. STRICKLER, Glass Research Center, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
12. **Crystal Orientation as Influenced by Platinum Nucleation.** GUY E. RINDONE, Pennsylvania State Univ., University Park, Pa.
13. **Kinetics and Molecular Constitutive Criteria for Glass Formation.** D. TURNBULL, General Electric Research Laboratory, Schenectady, N. Y.
14. **Nucleation Catalysis in Glasses.** W. D. HILLIG, General Electric Research Laboratory, Schenectady, N. Y.
15. **Kinetics of Nucleation and Crystallization Processes in Sodium Phosphate Glasses: Part 1, Nucleation and Crystallization of Sodium Trimetaphosphate Glass.** A. E. R. WESTMAN and M. KRISHNA MURTHY, Ontario Research Foundation, Toronto, Canada.
16. **Devitrification Kinetics of Fused Silica.** N. G. AINSLIE, C. R. MORELOCK and D. TURNBULL, General Electric Research Laboratory, Schenectady, N. Y.
17. **Nucleation and Crystal Growth Studies of Glass Melts.** FRANCIS C. LIN, Westinghouse Electric Corp., Pittsburgh, Pa.
18. **On the Structure of Glass and the Temperature Dependence of Crystal Growth.** S. D. BROWN and R. GINELL, University of Utah, Salt Lake City, Utah.
19. **Diffusion of Gold in Glass.** R. H. DOREMUS, General Electric Research Laboratory, Schenectady, N. Y.
20. **Summary of Symposium.** HOWARD R. SWIFT, Libbey-Owens-Ford, Toledo, Ohio.
21. **Theoretical Analysis of Convection Currents in Glass Tanks.** ALVE J. ERICKSON, Massachusetts Institute of Technology, Cambridge, Mass.
22. **Fundamentals of Glass Transmission Measurements.** H. A. KERRY, American Potash & Chemical Corp., Los Angeles, Calif.
23. **Fiber Glass: History and Prognosis.** ALEXANDER SILVERMAN, University of Pittsburgh, Pittsburgh, Pa.
24. **Stresses Introduced Into Glass by Replacing Alkali Ions Near the Surface by Other Alkali Ions from a Melt.** S. S. KISTLER, University of Utah, Salt Lake City, Utah.
25. **A Method for Investigating the Mechanical Properties of Glass Fibers Under Torsional Load.** JOHN F. MOONEY and EDWARD T. WEBER, III, School of Ceramics, Rutgers, The State University, New Brunswick, N. J.
26. **High Temperature Viscosity Determinations of Boron Oxide and Binary Alkaline Earth and Alkali Borates, with Special Emphasis on Rubidium and Cesium Borates.** PEI-CHING LI, ANIL C. GHOSE and GOUQ-JEN SU, University of Rochester, Rochester, N. Y.
27. **Fractography of Glasses Evidencing Liquid-in-Liquid Colloidal Immiscibility.** STANLEY M. OHLBERG, HELEN R. GOLOB, CHARLES M. HOLLABAUGH, Glass Research Center, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
28. **Influence of $TiO_2$ on the Dielectric and Other Properties of Transparent Glasses in the System $SiO_2$-$K_2O$-PbO-$TiO_2$.** B. V. J. RAO, International Resistance Co., Philadelphia, Pa.
29. **High Temperature Density Determination of Boron Oxide and Binary Rubidium and Cesium Borates.** PEI-CHING LI, ANIL C. GHOSE and GOUQ-JEN SU, University of Rochester, Rochester, N. Y.
30. **Oxygen Diffusion in Vitreous Silica.** EUGENE W. SUCOV, Glass Research Center, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
31. **Nuclear Magnetic Resonance Studies of Glass Structure.** PHILIP J. BRAY, Brown University, Providence, R. I.
32. **Gamma Irradiation Studies of Some Phosphate Glasses.** ADLI BISHAY, Argonne National Laboratory, Argonne, Ill.
33. **Apparatus to Study the Anelastic Behavior of Glasses.** FRANK J. MATUSIK, School of Ceramics, Rutgers, The State University, New Brunswick, N. J.
34. **Internal Friction and Viscous Flow in Glasses.** HAROLD T. SMYTH, School of Ceramics, Rutgers, The State University, New Brunswick, N. J.
35. **Compatibility of Hydrated Sodium Metasilicate Glasses with Inorganic and Organic Compounds.** EDGARD F. BERTAUT, Pennsylvania State University, University Park, Pa.
36. **Some Remarkable Effects of Pressure (Up to 200,000 Bars) on the Structure of Glass.** HOWARD M. COHEN and RUSTUM ROY, Pennsylvania State University, University Park, Pa.
37. **Effect of Water Vapor on the Kinetics of the Crystallization of Silica Glass.** FRANK E. WAGSTAFF, IVAN B. CUTLER and SHERMAN D. BROWN, Department of Ceramic Engineering, University of Utah.
38. **Dielectric Properties of Neo-Ceramic Glasses in the Systems $Bi_2O_3$-CdO-$SiO_2$ and $Bi_2O_3$-CdO-$B_2O_3$ and Their Relation to the Structure of Glass.** B. V. J. RAO, International Resistance Co., Philadelphia, Pa.

*April 23-27, Royal York Hotel, Toronto, Canada.

# NEW APPLICATIONS IN GLASS...

Glass blocks are being used extensively in wall construction, enabling a wide variety of color and design combinations.

### Glass Blocks in Architecture

Ceramic-face glass blocks, adaptable for either indoor or outdoor use, are now available in twelve colors. The colors, ranging from black and white through coral, orange, yellow, walnut, deep blue, green, and red, pastel blue and green, and charcoal grey, are fired on the faces of the blocks at extremely high temperatures.

A smooth-faced color-in-the-glass block with convex ribs on both interior surfaces serves to obscure vision while maintaining light transmission. *Kimble Glass Co.*

**Reader Service Card: Circle No. 56**

Hollow glass units with a design pressed in both faces and a fused-on ceramic finish on the outer surfaces are now being produced in eleven colors and four patterns—"Pyramid," "Wedge," "Leaf," and "Harlequin." The 12-in. square, 4-in. thick blocks, known as "Sculptured Glass Modules," are translucent and constructed with a partial vacuum which gives them excellent insulation characteristics. *Pittsburgh Corning Corp.*

**Reader Service Card: Circle No. 57**

Roof panels of prismatic, hollow, evacuated glass blocks have been designed to replace conventional non-directional, un-insulated skylights. They provide uniform illumination without the transmission of heat and glare. *Products Research Co.*

**Reader Service Card: Circle No. 58**

### Tempered Rough Plate Glass Doors

Privacy without any substantial reduction of light transmission is achieved through the use of ½-in. thick rough plate glass tempered doors in exterior building entrances and interior offices. The glass is said to be three to five times stronger than regular plate glass, and is available in three styles of the "Tuf-flex" line. *Libbey-Owens-Ford Glass Co.*

**Reader Service Card: Circle No. 59**

A stipple pattern surface, produced in a 9/32-in. thickness, is particularly suitable for interior partitions. *Pittsburgh Plate Glass Co.*

**Reader Service Card: Circle No. 60**

### Stained Glass and Aluminum in Decorative Panels

Stained glass sandwiched between two thin sheets of aluminum into which a design has been cut offers a broad range of possibilities for the decorative treatment of door and window openings in commercial and institutional buildings.

This new concept, known as "Metal Art Glass Panels," makes possible the production of sections up to 50 sq. ft. in size, whereas conventional stained glass is limited in practical area to 18 sq. ft. Processed from sections of blown glass surrounded by an epoxy resin, with web members varying in width, these panels are said to possess great flexibility and to make available designs never before possible. *Baut Studios, Inc.*

**Reader Service Card: Circle No. 61**

### Glass in Space Vehicles

Fused silica glass ("Code 7940"), available in industrial and optical grades, and microsheet optical grade glass ("Code 0211") are now being manufactured for use as solar cell covers on space vehicles. Both materials serve to protect these cells from high temperatures, thermal shock, and micrometiorites, and to transmit wavelengths utilized by the cells. *Corning Glass Works.*

**Reader Service Card: Circle No. 62**

### New Method of Phage Typing

A new concept ("Accu-Drop") in phage typing, antibiotic sensitivity testing, and sugar fermentation etsting has been developed and manufactured by Accu-Tech Corp. The equipment, which includes a glass syringe cartridge used as a holder for the phage, antibiotic, carbohydrate, or other biological reagent, is designed primarily to increase the accuracy of testing various biological and biochemical reagents against known or unknown bacterial cultures growing in petri dishes. Furthermore, the program permits the testing of many specimens with complete accuracy in a fraction of the time now required, and facilitates the rapid change from one testing procedure to another. *Sylvana Co.*

**Reader Service Card: Circle No. 63**

### CATALOGS RECEIVED

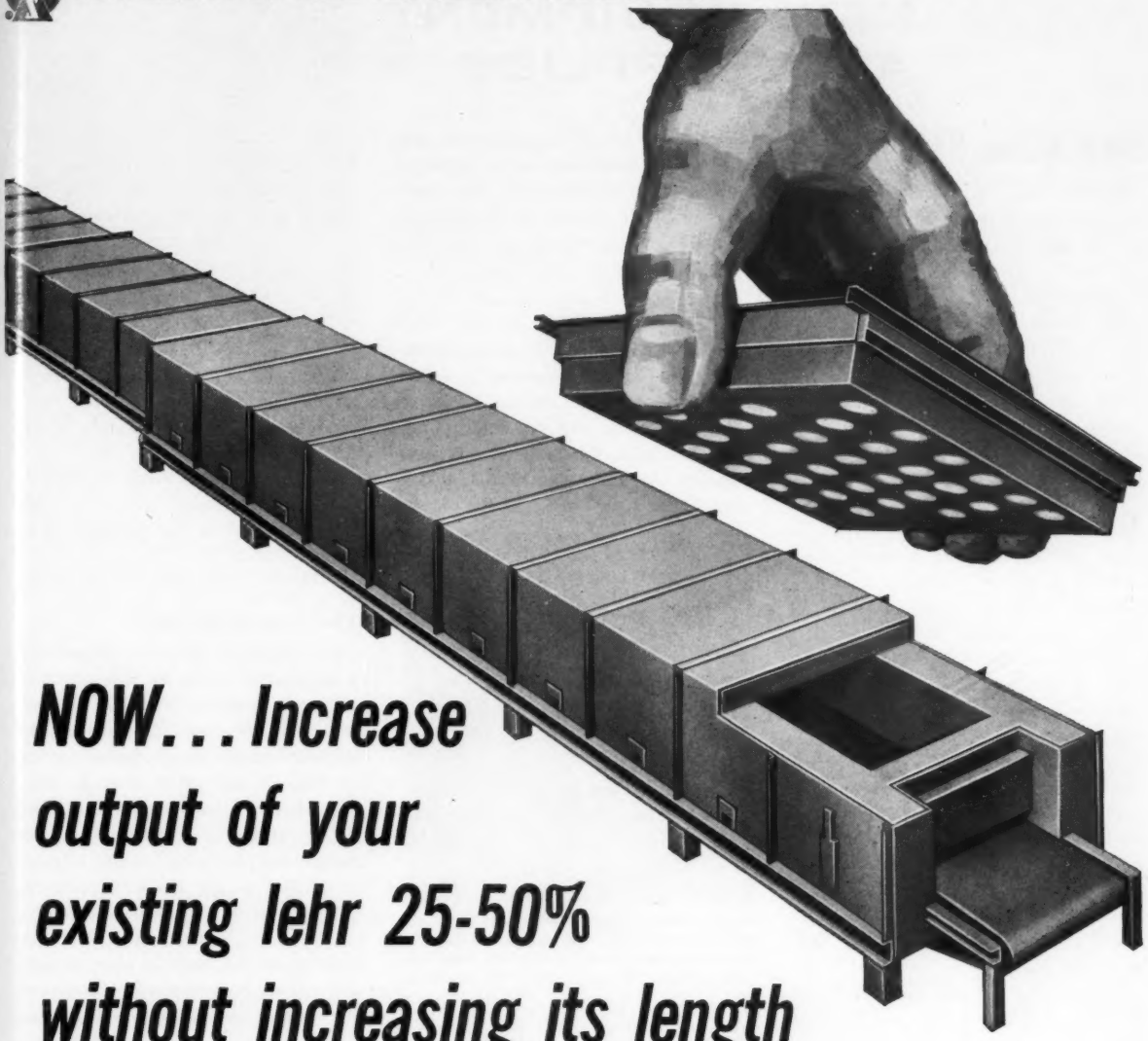
*Thermopane glass* (8 pages). Compilation of two previous booklets, "Standard Sizes — Manufacturers of Sash and Sliding Doors" and "Installation in a Simple Wood Frame." Includes sections on product characteristics, size limitations, sliding door manufacturers, glazing information, and a listing of standard sizes. *Libbey-Owens-Ford Glass Co.*

**Reader Service Card: Circle No. 64**

*Special glass products* (20 pages). 4-color, illustrated. The design and production of special glass products for specific application requirements. *Kopp Glass, Inc.*

**Reader Service Card: Circle No. 65**

*NEW SLANTS ON HEAT PROCESSING FROM SELAS*



# NOW... Increase output of your existing lehr 25-50% without increasing its length

By simply installing a Selas DURADIANT® burner roof panel into the preheat section of your existing lehr, you can significantly increase output . . . without adding so much as an inch to the length of the lehr. Over 40 installations have been made increasing production rates up to 50%!

By heating the ware directly from the top of the lehr—instead of overheating the conveyor from below—the Selas principle of direct-gas-fired, radiant-booster heating improves the performance of your existing lehr in other ways, too:

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**SELAS**

HEAT AND FLUID PROCESSING ENGINEERS
***DEVELOPMENT / DESIGN / CONSTRUCTION***

# NEW EQUIPMENT AND SUPPLIES

## New Glass Batcher

*Munson Mill Machinery of Utica, N.Y., has been manufacturing mixers for a variety of industries for some 45 years. After studying the rigid requirements for batch mixers in glass manufacturing, the company, by modifying their equipment, has developed a model for use in the glass industry. Five are now installed or scheduled for early operation in well-known manufacturing plants.*

On an actual production basis, this glass batcher can mix a coarse commercial batch in a minimum of 1½ minutes, while a high-quality blend may require double this time. The mixer will discharge clean in not more than 1 minute—in other words, the batch will empty completely from the mixer within 1 minute, providing the receiving equipment is of a capacity commensurate with the mixer's discharge rate, and on completion of the discharge, it is ready to be recharged with an identical batch. If the batch formula is changed, conventional cleaning methods must be used within the mixer and in all other material handling equipment.

When using an average density of 100 lbs. per cu. ft. for the average glass batch formula, the 30 cu. ft. mixer can be charged to 3000 lbs., or 1½ tons. Its capacity is one batch every 2½ minutes—or 1½ minutes for an average blend cycle plus 1 additional minute for discharge.

### *Internal Indicating Devices*

Limit switches are located in the discharge spout and are connected to indicator lights on the master control console. Their purpose is to *(1)* indicate that the discharge gate is closed following completion of discharge so that the subsequent batch can be charged into the mixer, and *(2)* indicate when the discharge gate is open and when the mixer is discharging. This automatically locks out, and guards against the possibility of accidentally introducing the succeeding batch before the mixer has discharged, a necessary precaution in an automatic and enclosed system where the batch operator has no visual means of knowing whether or not an operation has been completed.

### *Abrasion Resistance*

Because the blending of ingredients for glass is an extremely abrasive application and one which subjects all parts in contact with the batch to extreme abrasion, the parts in this glass batcher which are most vulnerable to premature wear are protected by

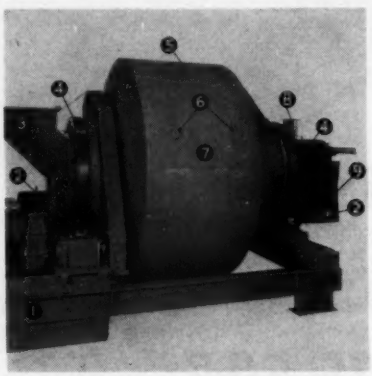


Fig. 1. Glass batcher: (1) supporting frame; (2) trunnion rollers; (3) intake hopper; (4) trunnion rings; (5) drum; (6) cam locks; (7) access door; (8) vent pipe; (9) discharge port.

replaceable wear plates. Lifters within the drum are designed to be readily replaceable, as this is where the major wear occurs.

All sizes of this glass batcher are fabricated from a high-strength, low-alloy steel plate having higher resistance to abrasion and atmospheric corrosion than carbon structural steel. By using this particular steel, says Munson, it is not necessary to use a liner in the drum.

The internal lifters, constructed of the same abrasion-resistant steel, are made to precise templates and can be installed in the mixer drum by the average maintenance laborer with no special tools and no welding or cutting. They are attached to permanent mounting lugs inside the drum through simple bolt assembly.

The drum incorporates a shallow cone at the intake end and a tapered cone at the discharge end. These are joined by a flat center section.

The door, located in the flat section of the drum, is attached by a continuous hinge. It is fabricated of heavy plate steel to resist warping or twisting and closes against a continuous rubber gasket which, in turn, is sealed to the drum. Two cam locks, attached to the drum, secure the door tightly against the rubber gasket. This door can be opened readily with a lever wrench for access to the drum interior to check the batch level or the condition of the drum.

### *The Discharge End*

The discharge spout is equipped with a radial seal to prevent leakage at the discharge end; it also encloses the retracting slide gate. The spout projects into the mixer at all times, but the opening in the spout through which the blended material discharges is closed off by a retracting slide gate during the blending cycle. At the completion of the blending cycle, the slide gate withdraws from the interior of the mixer, exposing the spout and allowing the discharge of blended materials. The gate operates in a horizontal plane, and the closing and opening action is provided by means of an 18-in. air cylinder which is mounted externally on the discharge spout.

Since most of the glass batcher installations are incorporated into closed systems, a vent pipe is provided in the discharge spout housing so that dust caused by the flow of blended materials into receiving hoppers can be safely vented or returned into the system ahead of the mixer intake.

A similar vent arrangement is provided in the intake spout to free the entrapped and replaced air within the mixer drum during the charging cycle. These vents contribute to a dust-tight and dust-free operation, and they also greatly increase the life expectancy of the drum seals. The displaced air within the mixer drum can escape through the vents, rather than be forced

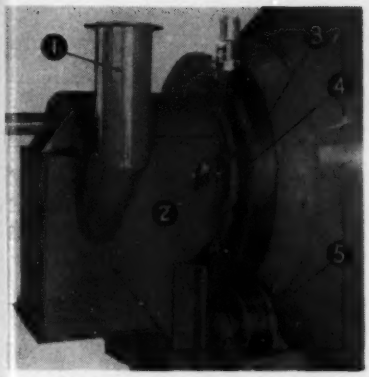



Fig. 2. Discharge end: (1) vent connection; (2) discharge gate housing; (3) trunnion ring; (4) radial seal; (5) trunnion roller.

through the seals, carrying particles of abrasive material into the seal members and contributing to accelerated wear.

The air cylinder operating the discharge gate is controlled from the master console or programming arrangement incorporated into the batch system. In some installations the gate is manually released through a push button at the control console, and closed in the same method. In other installations this operation is done automatically through program tenders.

### *External Drum Seals*

The glass batchers are equipped with external drum seals of a radial design which bear laterally against ground and polished wear rings. The seals themselves are stationary but can float laterally against the rotating wear ring. The contact between the seal unit and the wear ring is maintained by 16 equally spaced compression springs. An adjustment feature is provided to increase the compression of the springs in order to compensate for normal wear on the seal element.

The seal element itself is of a split one-piece design which might be compared to the design of a conventional piston ring. The mating ends of the split seal are made in a step-type arrangement so that when the element is installed, it is endless and is held in place by a compression band similar to a hose clamp. A replacement can be made by using a screwdriver to loosen and remove the clamped ring. No tools are needed to remove or replace the seal element itself.

The ground wear ring against which the seal operates is polished on both sides so that when wear has occurred on the original face of the ring, it can be reversed.

### *Lubrication*

The efficiency of the seal assembly is maintained through the use of oil lubrication which, in turn, is provided through solenoid-operated lubricators that carry an oil reservoir sufficient for several days' operation. These can be adjusted to provide the required flow of lubricant. The solenoid controls of these lubricators are connected to the motor control circuit so that the solenoid is actuated only while the drive motor is running. Whenever the drive motor is stopped, the solenoids close, shutting off the flow of lubricant. No danger of product contamination from the oil lubrication occurs, since any

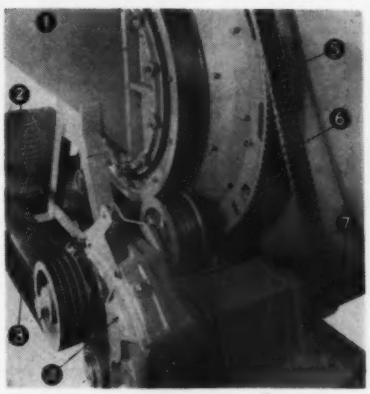



Fig. 3. Drive mechanism: (1) intake hopper; (2) motor; (3) V-belts; (4) speed reducer housing; (5) multiple-strand roller chain; (6) machined drum sprocket; (7) pinion.

excess of oil resulting from excessive flow or maladjustment of the lubricators remains outside the mixer and cannot contaminate the product.

**Reader Service Card: Circle No. 66**

### New Coating for Glass Containers

Is spray-applied and baked at temperatures ranging from 350°F to 550°F, using conventional spray and baking equipment. Called "Sterilkote 600," it is said to require only one application to the glass without any surface pretreatment and to produce high-gloss protective finishes that are resistant to acids, alkali, detergents, and solvents.

The coating can be supplied in a wide variety of colors, both transparent and opaque. Because of its strong chemical resistance and adhesion, it has, according to the manufacturers, wide application in the production of containers, drinking glasses, glass shelving, and lighting fixtures.

Where glass companies use many different colors, the new coating can cut production costs because manufacturers do not have to shut down their furnaces during color changes. *Bradley & Vrooman Co.*

**Reader Service Card: Circle No. 67**

### Low-Cost Truck Rental

Special-body trucks used in the glass industry can be leased without maintenance for from 4 to 8 years under the terms of a plan innovated for manufacturers and retailers. According to the new arrangement, the lessor will, without charge, engineer and supervise manufacture of bodies and chassis to the users precise specifications, deliver trucks to points designated by the user, base charges on special fleet discount prices, where available, and sell used equipment at the termination of the lease, proceeds of the sale going to the lessee. To qualify for a lease, the renting firm must have a net worth of $1 million and a record of profitable operations. *Wheels, Inc.*

**Reader Service Card: Circle No. 68**

### Stopcock Lock

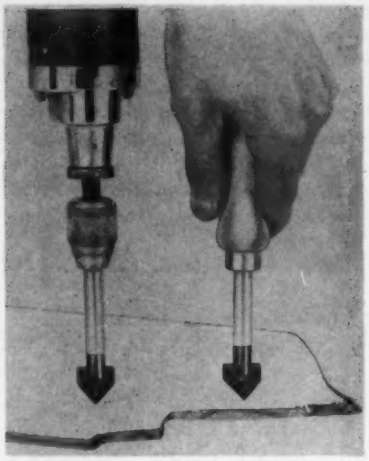
Provides positive locking action, yet permits freedom of rotation. Fabricated from Teflon and Marlex "50," the stopcock lock has no springs or clamps and is designed for use with standard taper glass stopcocks. It may be used with almost all laboratory reagents. *Fischer & Porter Co.*

**Reader Service Card: Circle No. 69**

### Silicone Embedding Compound

Provides mechanical and dielectric protection for electronic components and assemblies. Called LTV 602 (low temperature vulcanizing) clear silicone potting compound, it cures at 70° to 80°C to a flexible, resilient solid. It is self-supporting and non-flowing, providing for ease of handling as well as continual exclusion of dust and other contaminating particles. Components imbedded in the material can be readily identified, repaired or replaced by removal of a section with a sharp instrument. New material can be poured into the cutout section and cures without leaving evidence of repair. *Silicone Products Dept., General Electric Co.*

**Reader Service Card: Circle No. 70**



**Drill for Glass**

Can be used as a hand tool or, without handle, inserted into various power drills. Available in 1/32-in. through 1-in. sizes. *Smith Engineering & Tool Co.*

**Reader Service Card: Circle No. 71**

**Pneumatic-Tired Fork Trucks**

In 6000-, 7000-, and 8000-lb. capacity models have been introduced for handling work over piers, unpaved yards, and similar areas. The new series features fully-synchronized friction clutch transmission which permits shifting from forward to reverse without bringing the truck to a complete stop. *Clark Equipment Co.*

**Reader Service Card: Circle No. 72**

**Pyrometer Controller**

Heavy-duty millivolt pyrometer controller with solid state control units. It features a galvanometer sensing element, high-resistance input circuit, spring-backed jewel bearings for shock resistance, and minimum full-scale span of 10 millivolts.

The instrument is used in industrial processes requiring heat and measures such process variables as temperature, speed, vacuum, density, and electrical quantities. The entire unit measures approximately 10 in. wide by 8 in. high by 8 in. deep. *Weston Instruments Div., Daystrom, Inc.*

**Reader Service Card: Circle No. 73**

**Chart Recorder**

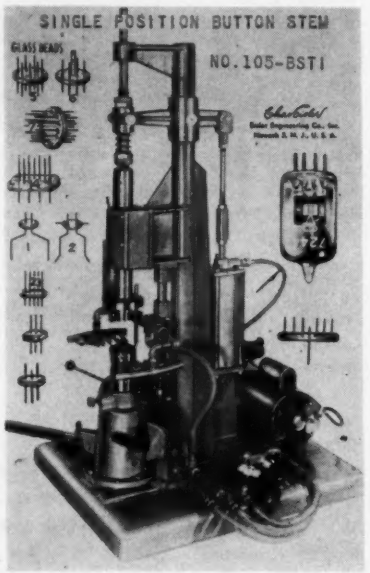
A two-pen potentiometric round-chart recorder-controller, accurate to within plus-or-minus one-quarter per cent, for use in any industrial application where two variables must be recorded on one chart. The measurement circuits may be potentiometric or bridge-type, or a combination of both. A hinged mechanism panel swings out to expose all measurement circuit components. Minimum scale spans are one millivolt dc. Available response times are 4, 10 and 24 seconds full scale. Pen speeds are 4, 10, and 24 seconds full scale, and chart speeds are 1, 8, 12, or 24 hours, or seven days. *General Electric Co.*

**Reader Service Card: Circle No. 74**

**Button Stem and Wafer Making Machine**

Developed to meet the requirements of a small product run on special tube parts, and also for laboratory use. All components, lead wires, the exhaust tube, and glass cylinders are loaded into lower press die. Preset fire heats glass parts to proper consistency, and upper die is lowered by actuation of the air control valve. Finished stems up to ¼ in. in diameter are removed after rotation is stopped by action of clutch arrangement. Machine is equipped with air-gas-oxygen or hydrogen-oxygen burners to handle all types of glass parts. *Eisler Engineering Co., Inc.*

**Reader Service Card: Circle No. 75**




**Cleaner and Polisher**

Designed for indoor or outdoor use is now available for cleaning mirrors, glass, plexiglass, polished marble, fiber glass, and all other nonporous surfaces. The product. called "Silicone Sparkle", contains a silicone cleaning agent. *Blake Products, Inc.*

**Reader Service Card: Circle No. 76**

**Marking Pencil**

An all-surface pencil for writing on film, wet and dry coatings, and on all glazed surfaces—glass, negatives, metals, laminations, etc. An improvement over standard grease pencils, it has a lead base of specially formulated graphite which is encased in straight grain cedar wood and can be sharpened in any conventional manner for fine detail work. *Joseph Dixon Crucible Co.*

**Reader Service Card: Circle No. 77**

**Break-Resistant Blades**

Designed for cutting light-weight block, dry press refractories, and softer types of stone feature a manufacturing process that weaves layers of tough, flexible glass cloth into each blade. Silicon carbide particles flow through the reinforcing mesh which protrudes beyond the surface, thus protecting the fiber glass cloth from becoming thin from side wear. Original break-resistant qualities are maintained throughout blade life. *The Clipper Mfg. Co.*

**Reader Service Card: Circle No. 78**

**CATALOGS RECEIVED**

*Ductile iron regulators and control valves* (4 pages). Details composition, properties, and specifications of the valves, comparing steel, cast iron, and red brass to ductile iron on the basis of a severe quence test on the latter. Includes a condensed listing of all the manufacturers products. *OPW-Jordan Corp.*

**Reader Service Card: Circle No. 79**

*Plant safety system* (12 pages). For plants using gas. Safety shutoff valves and supervising gas cocks act as mainsprings of the system, affording two-way plant protection. Bulletin also describes how system would work in a plant using fuel oil. *North American Mfg. Co.*

**Reader Service Card: Circle No. 80**

*Bin vibrators* (6 pages). Describes complete line of unit bin vibrators for handling all types of bulk materials. Nine models are available which require no rectifiers and provide pinpointed vibration for hoppers, bins and chutes. *Eriez Mfg. Co.*

**Reader Service Card: Circle No. 81**

*Rotary feed* (2 pages). For delivering and controlling the feed rate of dry, pulverized, and granular materials into high-pressure pneumatic conveying systems. *Fuller Co.*

**Reader Service Card: Circle No. 82**

# INVENTIONS AND INVENTORS

## Annealing and Tempering

*Apparatus for Bending Glass Sheets. Patent No. 2,957,277.* Filed October 12, 1953. Issued October 25, 1960. Seven sheets of drawings; none reproduced. Assigned to Libbey-Owens-Ford Glass Company by Gerald White and Frank J. Carson.

It is an aim of the present invention to provide an improved apparatus for annealing and cooling bent glass and to provide an apparatus for separating bent glass sheets from their associated bending molds so that they may be better and more uniformly annealed during passage through the cooling zones of the bending furnace.

Bent glass sheets are immediately removed from the bending surfaces of the molds as soon as the glass has reached a temperature at which the sheets are "set," i.e., at which they so closely approach their normally rigid structural condition that they will accurately retain their bent curvature without distortion. In an amplified form of the invention the bent sheets may subsequently be removed bodily from the mold to suitable supports upon which they can be carried through the cooling zones of the furnace until they have become completely and uniformly annealed.

The separation of glass and metal mold during the critical temperature span, as contemplated by this invention, makes it possible to set up more easily controlled annealing periods which may result in more rapid, as well as in the more uniform, annealing of the glass sheets. At the same time, the procedure permits more rapid return of the bending molds to the loading end of the furnace and the consequent reduction in the number of molds required.

There were 12 references and 1 claim.

## Feeding and Forming

*Apparatus for Centrifugally Forming Fibers. Patent No. 2,949,632.* Filed October 27, 1958. Issued August 23, 1960. Six sheets of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corporation by Dale Kleist and Henry J. Snow.

The object of this invention is to provide for the attenuation of very fine fibers of increased length, wherein the material is projected from a rotary centrifuge at a temperature sufficiently high for attenuation into a high velocity blast of gaseous medium from an annular blower. The blower surrounds the centrifuge and has one or more heaters which control the temperature of the glass but do not add heat to the glass after it first enters the centrifuge.

Among the concepts underlying the invention is the control of the temperature of the glass by proper operation of the heaters in order to control its rate of heat loss so that its temperature continuously decreases from the time the glass first enters the centrifuge until it is finally attenuated into fine fibers.

There were 15 claims and the following references cited in this patent.

**United States Patents**

2,328,714, Drill et al., Sept. 7, 1943; 2,497,369, Peyches, Feb. 14, 1950; 2,525,970, Spier et al., Oct. 17, 1950; 2,587,710, Downey, Mar. 4, 1952; 2,609,566, Slayter et al., Sept. 9, 1952; 2,624,912, Heymes et al., Jan. 13, 1953; 2,707,847, Anliker, May 10, 1955; 2,816,826, Brennan, Dec. 17, 1957, and 2,881,471, Snow et al., Apr. 14, 1959.

## Furnaces

*Apparatus for Producing Color-Controlling Vitreous Materials. Patent No. 2,955,384.* Filed February 27, 1958. Issued October 11, 1960. Two sheets of drawings; none reproduced. Assigned to Owens-Illinois Glass Company by William B. Silverman.

The apparatus in accordance with this invention consists of color-controlling mechanism adjacent to a glass retaining forehearth for incorporating into the batch of raw molten glass a moderating additive glass to intermix therewith and effect the color-controlling operation. The decolorizing or colorizing agent may be incorporated into an additive glass supply in a large proportion and intermixed with the main body of molten glass in the forehearth, one region of which serves as an intermediate homogenizing area. A homogeneous continuous stream of color-controlled molten glass free from streaks or cords is furnished in the downstream area of the forehearth immediately adjacent the location where the color-controlling glass is introduced. Thus, the operations of adding the color-controlling additive glass into the raw molten glass and rendering the mixture completely uniform may be accomplished in a continuous manner while the primary glass stream flows past an intermediate area of the forehearth to a point of use.

Control of the oxidized state of selenium is more easily accomplished in the present invention by the composition of the concentrated additives in the batch, the controlled melting and cooling of the selenium containing batch, and relatively short exposure to high temperatures where shifts in equilibrium may take place. Thus, selenium may be introduced in the oxidized form ($SeO_4$—) by incorporating nitrates or nitrate and arsenic in the batch. It may be utilized in the metallic form ($Se^0$) by oxidants, or rendered to the reduced state (Se— etc.) by reductants such as carbon. The precise state of oxidation of the selenium controls the exact shade of color imparted to the main body of glass for various purposes.

There was 1 claim and the following references cited in this patent.

**United States Patents**

576,312, Hirsch, Feb. 2, 1897; 805,139, Hitchcock, Nov. 21, 1905; 2,115,408, Brosse, Apr. 26, 1938; 2,148,345, Freudenberg, Feb. 21, 1939; 2,268,247, Fox, Dec. 30, 1941; 2,397,852, Gentil, Apr. 2, 1946; 2,538,956, Arbeit, Jan. 23, 1951, and 2,753,256, Olson, July 3, 1956.

**Foreign Patent**

667,474, Great Britain, Mar. 5, 1952.

(*Continued on page* 225)

# CURRENT STATISTICAL POSITION OF GLASS

**Employment** in the glass industry during December, 1960, was as follows: *Flat Glass*: a preliminary figure of 26,500 for December, 1960, indicates an increase of 3.5 per cent over the adjusted figure of 25,600 for November, 1960. *Glass and Glassware, Pressed and Blown*: a decrease of 2.8 per cent is shown by the preliminary figure of 85,300 reported for December, 1960, when compared with the adjusted figure of 87,800 reported for November, 1960. *Glass Products Made of Purchased Glass*: the preliminary figure of 14,300 given for December, 1960, is the same as the adjusted figure of 14,300 reported for November, 1960.

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**Payrolls** in the glass industry during December, 1960, were as follows: *Flat Glass*: a decrease of 0.4 per cent is shown in the preliminary $14,996,079.70 given for December, 1960 when compared with November's $15,062,478.59. *Glass and Glassware, Pressed and Blown*: a decrease of 5.2 per cent is shown in the preliminary $33,730,143.17 given for December, 1960, when compared with the previous month's adjusted $35,608,940.64. *Glass Products Made of Purchased Glass*: a preliminary figure of $4,889,413.53 was reported for December, 1960. This is a decrease of 0.5 per cent when compared with the adjusted figure of $4,914,817.91 for November.

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**Glass Container Production** based on figures released by the Bureau of the Census, Industry Division, was 12,285,000 gross during January, 1961. This is an increase of 9.7 per cent over the previous month's production figure of 11,195,000 gross. During January, 1960, glass container production was 12,669,000 gross, or 3.3 per cent more than the January, 1961, figure.

---

**Glass Container Shipments** during January, 1961, came to 11,594,000 gross, an increase of 1.7 per cent over December, 1960. Shipments during January, 1960, amounted to 11,108,000 gross, or 4.2 per cent less than January, 1961.

Stocks on hand at the end of January, 1961, came to 20,613,000 gross. This is 1.03 per cent more than the 20,402,000 gross on hand at the end of December, 1960, and 7.7 per cent more than the 19,123,000 gross on hand at the end of January, 1960.

## GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

**Narrow Neck Containers**

| | January, 1961 |
|---|---|
| Food | 1,126,000 |
| Medicinal and Health Supplies | 1,389,000 |
| Chemical, Household and Industrial | 877,000 |
| Toiletries and Cosmetics | 824,000 |
| Beverage, Returnable | 480,000 |
| Beverage, Non-returnable | 129,000 |
| Beer, Returnable | 88,000 |
| Beer, Non-returnable | 1,075,000 |
| Liquor | 648,000 |
| Wine | 441,000 |
| Sub-total (Narrow) | 7,077,000 |

**Wide Mouth Containers**

| | |
|---|---|
| Food | *3,444,000 |
| Medicinal and Health Supplies | 400,000 |
| Chemical, Household and Industrial | 149,000 |
| Toiletries and Cosmetics | 254,000 |
| Dairy Products | 148,000 |
| Sub-total (Wide) | *4,395,000 |
| Total Domestic | 11,472,000 |
| Export Shipments | *122,000 |
| TOTAL SHIPMENTS | *11,594,000 |

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

## GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

| | | Production January 1961 | Stocks January 1961 |
|---|---|---|---|
| Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics. | Narrow Neck | 4,353,000 | 6,890,000 |
| | Wide Mouth | *4,233,000 | *6,317,000 |
| Beverage, Returnable | | 679,000 | 2,321,000 |
| Beverage, Non-returnable | | 166,000 | 375,000 |
| Beer, Returnable | | 176,000 | 549,000 |
| Beer, Non-returnable | | 1,333,000 | 1,415,000 |
| Liquor | | 742,000 | 1,650,000 |
| Wine | | 437,000 | 790,000 |
| Dairy Products | | 166,000 | 306,000 |
| TOTAL | | *12,285,000 | *20,613,000 |

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

## CONDITIONS OF GLASS FORMATION

(*Continued from page* 200)

and that it causes a disproportionation of the binding forces in its surrounding leads to a superlattice rather than to a random distribution.

The formation of a superlattice on cooling and its randomization on heating will take place at different temperatures above as well as below the transformation regions depending upon the nature of the ions which are involved. On heating a glass $T_g$ is characterized as that temperature at which new major structural asymmetries can form on heating. These centers of asymmetry cause a disproportionation of all binding forces thus lowering the viscosity. Centers of asymmetry decrease the harmonicity of thermal vibrations thus increasing the expansivity. We look upon these defects or centers of an asymmetry of forces as the common denominators because their formation on heating is a feature which all solids have in common. The puzzling phenomenon that chemically unrelated substances resemble one another when they are in their glassy state is the result of the way in which glasses develop a higher defect concentration on heating.

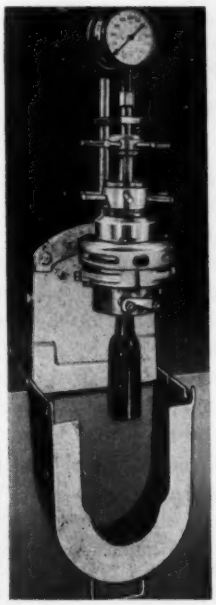
The effect which the symmetry has upon the thermal expansion can be applied to surfaces. Even highly symmetrical crystals or "flawless" liquids have surfaces, and surfaces are the seats of asymmetries which affect both the geometry and the binding forces. We assume that the greater anharmonicity of thermal vibrations within the surface layer of a glass causes the surface to have a higher thermal expansivity than its bulk. The greater thermal contraction of a glass surface as compared with the bulk causes the surface film to come under tension on cooling and the tensile stresses parallel to the surface may lead to rupture.

### PART IV REFERENCES


1. J. D. Bernal, a). The Faraday Society, London 1936, Discussion Volume, Structure and Molecular Forces in Pure Liquids and Solutions, p. 238. b). *Nature, 183*, 141 (1959).
2. J. Frenkel, Kinetic Theory of Liquids, The Clarendon Press, Oxford 1946.
3. W. A. Weyl and E. C. Marboe, *J. Soc. Glass Techn., 43*, 417 (1959).
4. J. Zarzycki, Non-Crystalline Solids, V. D. Frechette, Editor, John Wiley & Sons, New York, 1960, p. 117.
5. G. W. Stewart, a). *Kolloid Ztschr., 67*, 130 (1934). b). *Am. J. Physics, 12*, 321 (1944).
6. G. W. Stewart, The Faraday Society, London 1936, Discussion Volume, Structure and Molecular Forces in Pure Liquids and Solutions, p. 238.
7. J. A. Prins, Non-Crystalline Solids, V. D. Frechette, Editor, John Wiley & Sons, New York, 1960, p. 322.
8. J. J. Trillat and H. Forestier, *Bull. Soc. Chim. France, 51*, 248 (1932).
9. K. H. Meyer and Y. Go, *Helv. Chim. Acta, 17*, 1081 (1934).
10. L. C. Hoffman and W. O. Statton, *Nature, 176*, 561 (1955).
11. B. K. Banerjee, a). *J. Am. Ceram. Soc., 36*, 296 (1953). b). *Glastechn. Ber., 33*, 120 (1960).
12. M. Goldstein and T. H. Davies, *J. Am. Ceram. Soc., 38*, 223 (1955).
13. B. K. Banerjee, *Bull. Nat. Inst. Sci. India, 14*, 62 (1959).
14. W. A. Weyl, a). *Silicates Industriels, 22*, 458 (1958). b). *Bull. Central Glass & Ceramic Research Institute, India, 6*, 147 (1959).
15. H. H. Blau, *J. Soc. Glass Techn., 35*, 304 (1951).
16. E. Seddon and W. E. S. Turner, *J. Soc. Glass Techn., 17*, 324 (1933).
17. M. Karkhanavala and F. A. Hummel, *J. Am. Ceram. Soc., 35*, 215 (1952).
18. W. Oldekop, *Glastechn. Ber., 30*, 8 (1957).
19. H. R. Lillie, *J. Am. Ceram. Soc., 16*, 619 (1933).
20. P. Gilard, G. Henry and L. Dubrul, *Bull. Soc. Chim. Belge, 45*, 379 (1936) and *46*, 432 (1937).
21. E. Plumat, Trav. IV Congres International du Verre Paris 1956 VI 1, p. 299.
22. L. C. Hoffman, T. A. Kupinski, R. L. Thakur and W. A. Weyl, *J. Soc. Glass Techn., 36*, 196 (1952).
23. J. Zarzycki and F. Naudin, *Verres et Refractaires, 14*, 113 (1960).
24. A. Winter, Symposium Sur La Fusion Du Verre (1958) p. 301.
25. K. Endell and J. Hellbrügge, *Glastechn. Ber., 20*, 277 (1942).
26. H. Richter, G. Breitling and F. Herre, *Z. Naturforschung 9a*, 390 (1954).
27. G. Hägg, *J. Chem. Physics, 3*, 363 (1935).
28. L. Shartsis, W. Capps and S. Spinner, *J. Am. Ceram. Soc., 36*, 319 (1953).
29. F. C. Kracek, G. W. Morey and H. E. Merwin, *Am. J. Science, 35 A* 143 (1938).



**HYDROSTATICALLY TEST BOTTLES IN SAFETY**



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## RUBIDIUM IN LIME AND BORATE GLASSES

(*Continued from page* 193)

Table VII, excellent glasses appeared to be possible within the following limits of composition.

| | |
|---|---|
| $Rb_2O$ | 20 to 50 per cent |
| $B_2O_3$ | 10 to 50 per cent |
| $SiO_2$ | 10 to 50 per cent |

These limitations do not mean that good glasses are impossible beyond these areas, but glasses in excess of 50 per cent $SiO_2$ were very refractory while those in excess of 50 per cent $Rb_2O$ or 50 per cent $B_2O_3$ possessed poor durability.

TABLE VII

| Glass Number | Per cent Composition of Oxide | | |
|---|---|---|---|
| | $Rb_2O$ | $B_2O_3$ | $SiO_2$ |
| 12 | 30.0 | 10.0 | 60.0 |
| 13 | 20.0 | 20.0 | 60.0 |
| 17 | 40.0 | 10.0 | 50.0 |
| 18 | 30.0 | 20.0 | 50.0 |
| 19 | 20.0 | 30.0 | 50.0 |
| 23 | 50.0 | 10.0 | 40.0 |
| 24 | 40.0 | 20.0 | 40.0 |
| 25 | 30.0 | 30.0 | 40.0 |
| 26 | 20.0 | 40.0 | 40.0 |
| 31 | 50.0 | 20.0 | 30.0 |
| 32 | 40.0 | 30.0 | 30.0 |
| 33 | 30.0 | 40.0 | 30.0 |
| 34 | 20.0 | 50.0 | 30.0 |
| 35 | 10.0 | 60.0 | 30.0 |
| 40 | 50.0 | 30.0 | 20.0 |
| 41 | 40.0 | 40.0 | 20.0 |
| 42 | 30.0 | 50.0 | 20.0 |
| 43 | 20.0 | 60.0 | 20.0 |
| 44 | 10.0 | 70.0 | 20.0 |
| 50 | 50.0 | 40.0 | 10.0 |
| 51 | 40.0 | 50.0 | 10.0 |
| 52 | 30.0 | 60.0 | 10.0 |
| 53 | 20.0 | 70.0 | 10.0 |
| 54 | 10.0 | 80.0 | 10.0 |

The influence of $Rb_2O$ was most effective: 20 per cent appeared to be needed to obtain a good glass, while the fact that 50 per cent $Rb_2O$ was possible without devitrification or poor durability is quite unusual.

The very high content of $B_2O_3$ possible with these glasses is unusual and is believed to be due to the beneficial effects of $Rb_2O$, providing increased viscosity and durability. The only difficulty noted with the very high $B_2O_3$ glasses—that is, members 52, 53, and 54 (60 to 80 per cent $B_2O_3$, respectively)—was the lack of durability. This limitation could, no doubt, be corrected.

With an increase in the amount of $Rb_2O$, the density and the index of refraction appeared to increase. As the amount of $SiO_2$ was decreased, the glasses became softer with lower softening points and higher coefficients of expansion.

### *Recommendations for Future Work*

Because all the melting done in this investigation was conducted about 1500°C, future work is needed to determine more accurately the melting conditions needed

for each glass. In view of the fact that these glasses showed so much promise, other systems substituting $Al_2O_3$ and MgO might be tried.

Another possibility for future work might be a systematic study of the combination of various alkali ions with rubidium; little is known concerning the specific effects of blending alkali ions in glasses. This type of study has been most helpful in the improvement of phosphate glasses. Other properties such as electrical conductivity at elevated temperature, dielectric loss, durability, and transmission characteristics could be determined for the more encouraging glasses. Particular interest might also lie in the effects of $Rb_2O$ on color.

## FIRE FINISHING OF GLASSWARE

(*Continued from page* 188)

an interesting family of materials which devitrify after forming. In both types, fire finishing of top edges is required to remove sharp mold marks. All of these compositions are in the higher temperature ranges, and therefore require more flame intensity for fire-finishing operations. Burner contours are usually shaped to the ware, as shown in Fig. 9, and intensity is increased either through preburning in "miniature furnaces" as shown, by substituting oxygen for combustion air, or by replacing part or all of the methane in natural gas with a faster burning fuel component.

### *Flat Glass*

Shelves, jalousies, and similar items of plate glass are often fire finished along one or more edges to produce a smooth or bulb edge. These, after cutting to size and preheating, are usually conveyed along straight-line, sharp-flame burners, one edge at a time in vertical position, or two edges at once in horizontal position, and then rotated to treat remaining edges before reannealing or tempering.

### *Rods and Tubing*

Because of their uniformly round cross section, tubing and rods (also called "cane") can usually be fire finished without preheating; e.g., the once-popular glass highball stirrer was cut from cane and its ends exposed on a conveyor to straight-line (ribbon) burners whose lengths determined ball diameters on the rod ends.

A simple setup for fire glazing ends of larger tubing is pictured in Fig. 9, where a single high-intensity burner brings the rotating ware edge preferentially up to fusing temperature. This can be easily projected into high-production equipment.

### *Reflective Beads*

Our first-page definition of fire finishing would exclude such operations as hot roll-forming, fiberizing, and most sealing of tubes and ampules, even though these may involve remelting of surfaces. It would include, however, the production of fine glass beads, although this may be considered a special case. In the bead-making operation, selected cullet is crushed and the screened

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particles dropped through a hot tower—usually flame-filled. Not only the entire surface of the particle is fused, but in most cases, all of the material within it. After sufficient flame exposure to convert the irregular surfaces to spheres, these spheres leave the heated zone and cool sufficiently to be collected as beads and classified.

### *Machines*

It has been often observed that most machines for fire-finishing service—of which there are several types—are generally equipped with mechanisms which are far in advance of their combustion equipment. Consequently, much of the existing fire finishing can be—and has been—improved materially by the replacement of combustion equipment with that which fulfills the *five requirements*. It is indeed gratifying to observe the advent of improved fire-glazing machines, but even these must be properly selected and applied to produce satisfactory results. One of the newer machines which has been producing good results is shown in Fig. 10.

### *Future Developments*

The acceleration of development work in fire finishing continues unabated. Numerous studies are now under way to produce methods and equipment which will increase both quality and speed of customary finishing


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operations, and extend the benefits of fire finishing to additional types of ware. Further, operations which have long been performed by mechanical or chemical methods are now being carefully scrutinized to determine whether significant economies can result from substitution of properly controlled flame treatment. And there is good reason to believe that they will.

## INVENTIONS AND INVENTORS

(*Continued from page* 219)

### Sheet and Plate Glass

*Method and Apparatus for Polishing. Patent No. 2,945,333.* Filed June 2, 1950. Issued July 19, 1960. No drawings. Assigned to Societe Anonyme des Manufactures des Glaces et Produits Chimiques de Saint-Gobain, Chauny & Cirey, by Robert Touvay and Philippe Tommy Martin.

This invention relates to the polishing of glass and particularly to the polishing of flat glass. The objects of the invention are accomplished by a combination including a polishing tool having a polishing face composed of rubber or a rubbery synthetic resin and by supplying the tool continuously throughout the polishing with a suspension of polish in liquid. The cost of polish is reduced by this invention because the invention makes it possible to use the detritus from previous polishing operations as the polish in subsequent operations.

The invention is based upon the principle of carrying out the polishing throughout with an abundant supply of polish suspended in liquid, but employing a tool having a working face which possesses at all times a rigidity of the same order as that of felt during the dry stage of standard practice.

There were 9 claims and 16 references cited in this patent.


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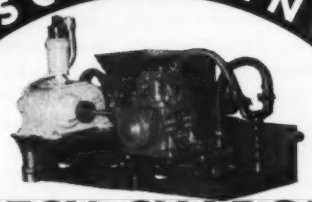

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